A Systems Approach to the Development of Large Geographic Information Systems

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Declaration

I hereby declare that this thesis is my original work and has not been submitted in any form to another university.

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Abstract

Large computer-based information systems seldom achieve unqualified success. The major problem is organisational rather than technical, hence to achieve greater success in system implementation greater emphasis must be given to organisational issues than to technology. Current practise, however, tends to focus on technical issues.

The aim of this research was to investigate whether a systems-based approach would lead to better understanding of the system development process, and hence form the basis of a methodology which would lead to greater success in computer-based information system implementation.

The thesis comprises four parts. In the first part (Chapters 1 - 5) the literature on systems theory in sociology with particular reference to business organisations is reviewed. This review focuses on the historical development of systems thinking, particularly in business management. Beer's Viable System Model, Checkland's Soft Systems Methodology, and Hoebeke's ideas on the adoption of new technology provided the main ideas for developing a conceptual model for the information system development process.

In the second part (Chapters 6-9) this model is applied to the information system development process to identify the strengths and weaknesses of current methods. Each stage of system development from planning to implementation is considered from a systems perspective. This involves identifying the key stakeholders, and understanding their role in the development process.

In the next part three case studies are examined in the light of the theoretical material. The impact of inter-cultural communication is highlighted in these studies as the developers and customers were from several different cultures. The author was personally involved as project manager and chief consultant in the development of two of the systems described. He was also fully aware of the progress of the other case because that development was being undertaken in the same office. Regular exchanges of views on the progress of each project took place.

In the final chapter the conclusions are presented. The main conclusion is that information system implementation must be undertaken within the overall context of the organisation, must be closely aligned with the organisational

business processes, and must address the conflicting needs of the different stakeholders. Effective Communication between system developers and system users is crucial to success. A focussed effort is required to achieve effective communication in a multi-cultural environment.

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For this reason the design and implementation of the system cannot be carried out successfully without taking into account the impact on the organisation and without finding ways to promote the necessary changes.

1.2 Problem Statement

There is a general acceptance that large and complex computer system installations are seldom entirely successful, for example Pressman (1992 p.18) writes "*Customer dissatisfaction with the completed system is encountered too frequently. Software development projects are frequently undertaken with only a vague indication of customer requirements. Communication between customer and software developer is often poor.*" Wessel (1979 p.2) writes "*Even when partially successful, information systems seldom function in direct conformance with the original purposes. A significant degree of complex adaptation occurs during implementation - adaptations of user organisation, system, system functions, and overall as well as specific systems goals.*" Writing in (Stowell 1995 p.18), Mingers cites several examples of contemporary large scale total failures including the London Stock Exchange Taurus system (£75m). He also quotes a report from the US General Accounting Office on US federal government software projects, stating that 47% of the systems studied were delivered but never used.

Despite the requisite technology being both reliable and available, it is apparent that large information systems seldom achieve the degree of success that their developers and promoters would wish. For example operators may continue doing some tasks manually although the computer system is available. The problem is more acute with systems using advanced information technology such as geographic information systems, systems using multi-media, complex engineering software etc.

The question is: <u>to determine whether a particular approach to system development could lead to a higher success rate, and, if so, what that approach should be</u>.

1. INTRODUCTION

1.1 Background

Information technology is playing an ever-increasing role in our lives. It is particularly important in organisations, government and private, which are being forced by competitive pressures both to increase productivity and to reduce costs.

Computers have been used as business tools for more than forty years but it is only now that information technology is becoming directly relevant to virtually every member of the workforce. Until quite recently corporate electronic data processing (EDP) was the preserve of a small group within the organisation. This group of computer specialists handled the financial system, payroll, personnel records etc. A continuing fall in the price of computer hardware, coupled with increasing power and performance and more user-friendly software, has brought distributed client/server or 'end-user' computing, based on high-speed networks and powerful PC's, to every desk.

Though the computer started out as an electronic calculating machine, a tool to assist business operations, today's computer-based information system is much more than a tool. It is a composite man-machine system functioning within a social organisation. The modern computer-based information system is an integral part of the organisation and its use involves in some way or other, all the members of the organisation. Unfortunately, maximising the benefits of information technology requires change in the organisation. This is inevitably painful for some members and may provoke resistance. Lundeberg *et al.* (1981, p.125) writes "*Information systems have value only if they contribute to improve the situation for people in the organisation. They have no value of their own. It is therefore not enough that we study the contents of the information systems so that we can form an opinion about their value. We must instead study the activities that people perform in the organisation and that somehow should be improved.*"

1.5 Contributions of this Research

This research has led to a better understanding of the system development process which is encapsulated by the conceptual model proposed. Leading from this understanding, a system development methodology is described which can be used for any large scale IT planning and development project.

Because of its systems foundation, the methodology is able to highlight key environmental (non-technical) and cultural factors which may differ from project to project, but which must be taken into account to ensure the success of the project. Such factors might include government attitude to secrecy, threats to employees' power or job security, personalities of key development team members etc.

1.6 Research Method

Researchers take a number of approaches to the collection of knowledge. The approach used in any given case will depend largely on the subject being investigated. "Scientific method" is appropriate when hard facts about the physical world are being studied. In this century, sociology has attempted to portray itself as a science, but there are many who take issue with this. The roots of sociology are in philosophy and spring from the writings of Hobbes, Lock, and Hegel. Hence "scientific method" as espoused by positivists is not a suitable tool for research in sociology. The positivist or verificationist view has prevailed in the past two centuries in natural science though it is now increasingly under attack, and is in sharp contrast with the approach to system development taken in this study.

Encyclopaedia Britannica states: "*The basic affirmations of Positivism are (1) that all knowledge regarding matters of fact is based on the "positive" data of experience, and (2) that beyond the realm of fact is that of pure logic and pure mathematics, which were already recognised by the Scottish Empiricist and Sceptic David Hume as concerned with the "relations of ideas" and, in a later phase of Positivism, were classified as purely formal sciences. On the negative and critical side, the Positivists became noted for their repudiation of metaphysics; i.e., of speculation regarding the nature of reality that radically*

1.3 Objectives of the Research

The ultimate goal of this research is to produce effective information systems at lower cost through providing a development methodology based on sound theory.

Two steps are involved -

- to use systems theory as a basis to develop a conceptual model for the information system development process, and
- to use this model to construct a development methodology which identifies and avoids weaknesses of current methods.

1.4 Hypotheses

One hypothesis advanced is that

> *a conceptual model based on systems theory can provide the basis for an effective system development methodology.*

A further hypothesis following from this is that

> *A suitable organisational model can be used for business process re-engineering, quality management, information system planning and information system design and implementation.*

The initial assumptions are:

- An effective computer-based information system forms an integral part of the organisation in which it operates.
- The implementation of a computer-based information system requires a synthesis of the (pre-computer) organisation and the computer system to produce a transformed organisation. i.e. organisational change.

In a multi-cultural environment one also has to remember that the individual members of the human activity system may not share the same understanding of the task being done and their roles in it.

The basic epistemology adopted here is 'interpretive', that is to say, access to reality is through what Myers calls "social constructions" such as language, consciousness and shared meaning. This is illustrated in Figure 1-1 below which shows how observation of events and communication between observers and participants is filtered by language and cultural perceptions, while understanding is embedded in a common consciousness.

Qualitative sociological studies are commonly undertaken through:

a) Ethnographic Research
b) Case Study Research

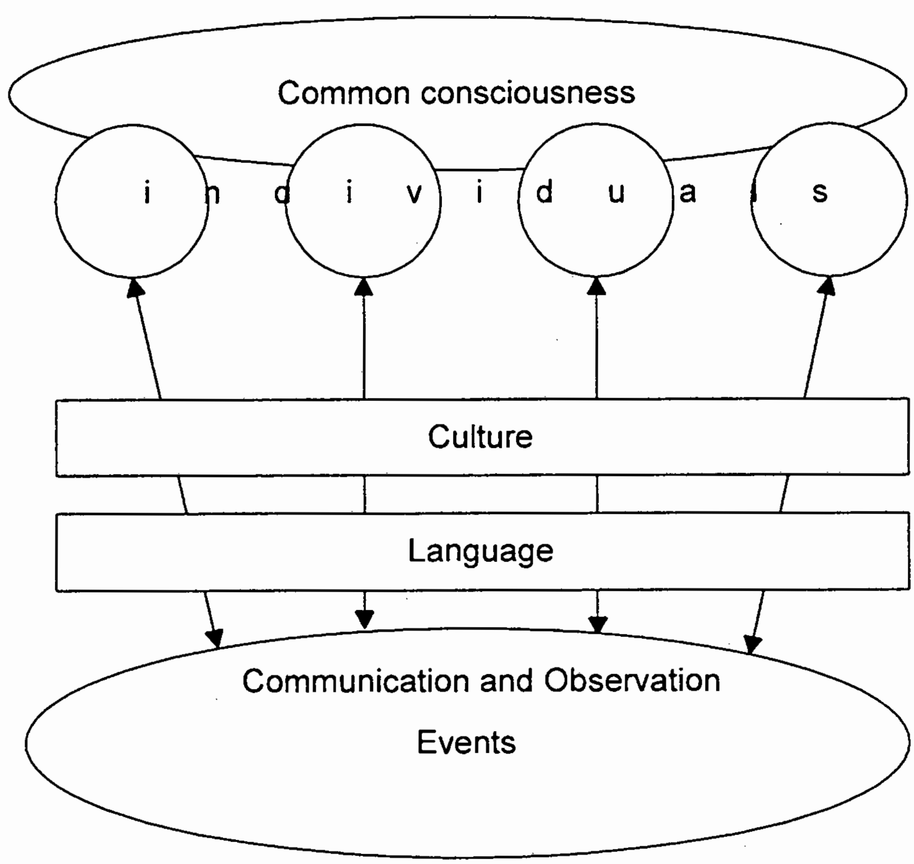


Figure 1-1 The Epistemology or Pattern of Understanding

goes beyond any possible evidence that could either support or refute such "transcendent" knowledge claims. In its basic ideological posture, Positivism is thus worldly, secular, antitheological, and antimetaphysical. Strict adherence to the testimony of observation and experience is the all-important imperative of the Positivists."

In contrast, Checkland writes "*Rather the work* (of Chomsky) *lends support to the view that the investigation of social reality is* ***fundamentally*** *different from the investigation of the natural world.*" He continues "*Because a model of a human activity system will express only one particular perception of a connected set of activities out of a range of possibilities, we cannot expect the kind of match between reality and model which natural science seeks, and which it is possible to achieve in the case of natural systems.... But when a model of a human activity system does not match observed human activity the fault might be the model builders but it might also be due to the autonomous real-world behaviour of human beings.*"

Two approaches are commonly taken in sociological research - qualitative in which descriptive data is collected by direct observation, from informants, and from literature, and quantitative in which data, collected from sample populations through questionnaires and interviews, is reduced to numerical statistics. Quantitative data is useful when facts are involved - facts like median income, proportion of population with tertiary education, proportion owning their homes etc., and when statistically significant sample sizes are used. However, statistical data is of very little use in studying opinions - pollsters forecasting economic trends or election results are notoriously inaccurate.

Extensive research looks at the behaviour of large groups and tries to deduce common elements, while intensive research looks at the behaviour of individuals, the reasons for, and the effect of their behaviour. Both are relevant to systems research.

In dealing with information system development one is working with relatively small groups where individual actions may have a major impact on the outcome. At the same time, by creating an appropriate system, the developer attempts to constrain the behaviour of individuals so as to produce a pre-defined outcome.

views of a population, but to deepen his or her understanding of a social phenomenon by conducting an in-depth and sensitive analysis of the articulated consciousness of actors involved in that phenomenon. Interview transcripts and field notes are read by the ethnographer, for the same purpose that academic texts are also considered, that is, in the hope of finding fresh insights and new ways of understanding a particular phenomenon. Positivist criteria of validity are quite inappropriate to this process, their imposition reduces ethnography to the status of a 'poor relation' of quantitative research - a means of gathering sensitive information, but ultimately less valid."

The research carried out here is principally ethnographic, although three major cases are considered. Information has been collected over a number of years spent in planning and implementing large geographic information systems.

Working in the field of information systems planning and development, one acquires a knowledge of the techniques which work and those which do not. When a technique, effective in one project, fails in the next, one is driven to analyse the factors responsible.

In any research project, criteria for assessing results are important. In the case of information systems success and failure are seldom absolute since a system which is successful from one point of view may be a failure from another perspective.

Generally used criteria include:

- completion on time
- completion within budget
- compliance with functional requirements
- meeting the expectations of users

The last criterion represents the common sense approach. Bronzite (1991, p.11) suggests that a measure of this success is whether the customer is prepared to recommend the system consultant/vendor to other customers a year after the system hand-over. This implies customer satisfaction and a continuing positive relationship.

1.6.1 Ethnographic Research

This form of research comes from the field of social and cultural anthropology. The ethnographer spends a significant amount of time in the field "*immersing himself in the life of the people he studies*" [Lewis 1985]. This approach is being increasingly adopted in the study of information systems. [Hughes 1992; Orlikowski 1991; Preston 1991]. In this case the writer has been immersed in the world of system development for ten years both as a participant and as an observer.

In a non-western environment one faces an additional problem in that system developers tend to come from diverse cultural backgrounds. Their 'technological' (broadly speaking 'Western') education will have conveyed ideas and methods to them, which may conflict with their traditional cultural values.

1.6.2 Case Studies

Case Studies form the most common form of qualitative research. No doubt one of the main reasons for this is that it provides a defined and limited context for students and academics to study post facto. Ethnographic research on the other hand requires a long-term commitment.

Case studies depend primarily on interviews and documentary material while participant observation provides the main data collection method for ethnographic research.

1.7 Appropriateness of Research Method

Wainwright notes that qualitative research has gained a new respectability in the past decade, but only at the cost of embracing positivist criteria of reliability and validity. He writes "*This transformation* (from interpretivism to positivism) *is legitimised by the bogus belief that positivist criteria of validity confer a degree of authenticity upon research findings.*" And he continues "*The importation of positivist criteria of validity into the qualitative research process is not only unjustified on the grounds of scientificity, it is also grossly inappropriate for the type of knowledge produced by such a perspective. The aim of the qualitative researcher is not to produce a representative and unbiased measurement of the*

1.8 Conceptual Foundations

Stafford Beer (1981, p.18), a pioneer of the systems approach to management wrote "*There can now be, indeed at some point there certainly will be, some kind of merger between man and machine - a symbiosis.*". With respect to GIS, Richard Groot (1992, p.122) states "*It speeds up transactions; it makes the hierarchical way of operating less relevant. It also has a major effect on how organisations relate to one another. It therefore affects the way organisations need to be structured.*"

There are various ways to view the introduction of GIS into an organisation. Campbell (pp. 26-41) mentions three -

> **Technological Determinism** - The view that if the technology is good, it will be adopted, and that the only obstacles to successful implementation are poor technology and stupid users. This view is founded on a positivist epistemology which is rejected here.
>
> **Managerial Rationalism** - The view that individuals in organisations behave rationally and follow the lead taken by senior management. 'Rationality' may have several meanings (see Section 3.1.1), and it is clear that Campbell has adopted a restricted meaning, that of behaving and deciding only on the basis of logical propositions, rather than on the basis of customs, norms, emotions and beliefs. The latter meaning is adopted here as it seems to be the only way in which a multi-cultural environment can be addressed. Davies (pp.16-17) writes "*...one form of rationalising can seem extremely irrational to a non-member of that culture, who will have a different set of values, beliefs, etc.*"
>
> **Social Interactionism** - The focus is much more on the culture and politics of the organisation but tends to overlook the coercive powers that managers can use.

The approach taken here combines features of managerial rationalism with some features of social interactionism. This approach flows from the systems perspective of the organisation. Systems theory provides the tools to study the organisation, the computer-based information system and the interaction which takes place during the design and implementation process.

The study of systems, and *general systems theory* in particular, is a relatively new discipline which aims to classify systems of every kind - natural, mechanical, biological, social etc. - in order to integrate them by identifying common processes. That the study of systems is a recent development is due to the enormous success of *scientific method* in bringing about the unprecedented technological revolution of the past four hundred years. The universal adoption of *scientific method* based on a logical positivist epistemology has undoubtedly been responsible for the enormous leap forward in science and technology in modern times. This method relies on three concepts - *reductionism*, *repeatability* and *refutation*. The essence of *reductionism* is to build hypotheses by carrying out controlled experiments in which selected parameters are varied while all others are held constant. *Repeatability* means that these experiments can be validated by repeating them and obtaining the same results. Invalid hypotheses can be *refuted* by the failure of experimental evidence to support them. The scientific method carries with it an implicit belief that the individual components of a system behave in the same way when isolated in scientific experiments as they do when interacting with all the other system components.

A reaction to reductionist thinking began in the early twentieth century, and one of the earliest works proposing what is now known as 'systems thinking' was *Holism and Evolution* by J.C. Smuts, published in 1926. He wrote (1926, p.2) "*The double mistake of abstraction and generalisation has thus led to a departure in thought from the fluid procedure of nature. This narrowing of concepts and processes into hard and rigid outlines, and their rounding off into definite scientific counters temporarily simplified the problems of science and thought, but <u>we have outlived the utility of this procedure</u>,...*" From this point on, the development of systems thinking has been rapid, especially since 1960.

A recent attack on reductionism as a tool to explain emergent characteristics of systems is contained in the book "The Collapse of Chaos" by Cohen and Stewart (1994). They call their approach 'contextualism' because they believe that the patterns which emerge in complex systems are largely due to the context of the system. They write (p.398) "*'Holism' isn't quite the word we want; holism is certainly an alternative to reductionism, but it considers a system as a unit and often ignores its context.*" It is not clear whether Smuts who coined the term, would equate 'holism' with open systems but as will be shown below, the open systems approach sees every system as embedded in a super-system (or metasystem) and operating in, and constrained by, a surrounding environment very much in the 'contextualist' manner.

The systems approach to the study of organisations is now widely adopted and continues to gain ground, though not without critics. Criticism appears in most cases to be based on a misunderstanding of the systems approach (see Hodge 1988, p.62) and to rest on three points:

- it over-simplifies the organisation,
- it is too abstract to apply in practice,
- it tends to favour centralisation.

With regard to the first point, it is fair to say that linear systems models fail to take account of individual human creativity and are not therefore an entirely suitable model for human society. Researchers in the field of organisational theory have recognised this, and now make extensive use of non-linear models (see Stacey 1993).

The second point is becoming less relevant as on-going advances in computer technology provide the power to analyse ever more complex models.

The third point arises from a particular political view - some systems practitioners may favour centralised systems, but the modelling approach is equally valid for centralised and distributed systems. In fact modern distributed database technology allows data to be physically decentralised, yet to appear to users as though it were in a central database.

Robert Lilienfeld (1978, p.247) after a very comprehensive account of Systems Theory, claims that the theory is an analogy, despite denials by its protagonists; that the theory has no practical value other than in the narrow area of communications theory; and finally, that it represents a determinacy in science which is rejected by many scientists. He adds (p.255) "*The notion of cybernetics-information-communication theory, then, of life as a set of determinate information-patterns is based on an already outmoded ontology. Ashby's idea ...is so absurd as to constitute a puzzle: how was it taken seriously? The answer, of course, is the persistence of outworn thought patterns and the difficulty experienced by many scientists, let alone system thinkers, in throwing off these habits of thought.*" His criticism appears at times to be somewhat irrational and to be based to some extent on a personal dislike of authority. His conclusion that systems theory represents 'determinacy' in science is strange, given that systems theory arose in reaction to reductionism, itself an aspect of determinacy, and that systems theory admits deterministic and non-deterministic systems.

Despite criticism, systems theory is well established in automation and communication, and continues to gain acceptance within the social sciences. It is held that the theory provides a useful framework in which to plan and implement computer-based information systems.

The key concepts used in this study include **General Systems Theory,** a theory which seeks to describe features common to all systems, and **cybernetics,** defined by Norbert Wiener, its founder, as a '*science of control and communication in mechanisms, organisms and society*' (1948, p.3) but now regarded as a general theory of control, applicable to any system which forms a sub-system of general systems theory. Cybernetics can be used to describe and explain a class of systems called '**automata**' of which the digital computer is a member. Cybernetics is also the basis of the theory of a special class of systems - **open systems** which interact with their environment in such a way as to maintain themselves.

In the field of organisational studies, numerous open system models have been proposed. These include Peter Checkland's **soft system** and Stafford Beer's **viable system.** Flood and Jackson (1991, p.11) categorise the latter as a **neurocybernetic model** i.e. a model based on an analogy with the human nervous system. Stafford Beer used this analogy extensively in his writings, but it must be remembered that it is an analogy, not an identity. Viable systems include organisations and computer-based information systems (**CBIS**) which are hybrids, comprising automata (the computers) and an organisation (the people who run the system).

System implementation involves two organisations - the target organisation and the implementation team. Human activity systems or "soft" systems, in particular **culture** and **politics**, play an important role in organisations; this too must be taken into account. The approach is illustrated in Figure 1-2 below.

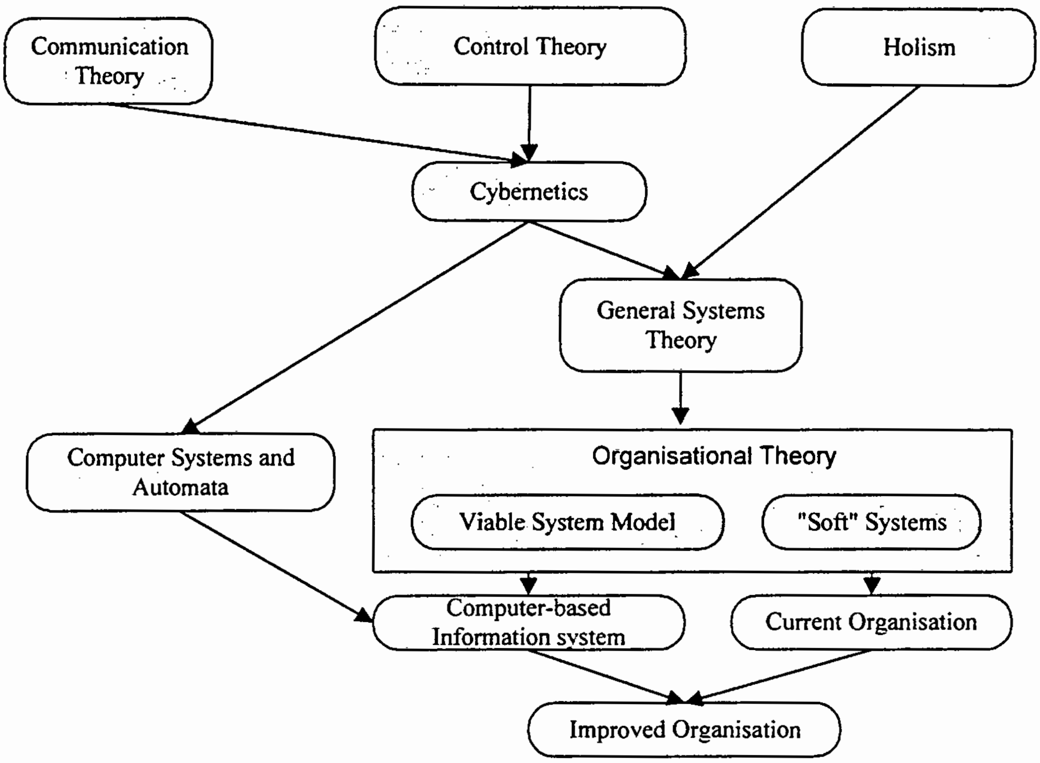


Figure 1-2 Application of System Theory to Organisations

Stafford Beer's Viable System Model has been adopted as a starting point. This model has been refined through a study of other writing on the topic, and by testing against actual situations encountered in a number of system development environments.

Once the appropriate conceptual model was available, the analysis of day to day project events was greatly simplified; it was possible to test events to see if, and how, they fitted into the model.

As a result, the development of the system model described below, has led to a much clearer understanding of the tasks and activities in the information system development process.

1.9 Scope and Limitations

This study is concerned with larger systems comprising several workstations and numerous peripherals linked to a database server or servers by a network. The methodology proposed may not be suitable for smaller systems where it might be considered 'overkill'.

The scope of the study is confined to the system planning and development methodology. Technical issues relating to system development are not considered. The assumption is made that, when embarking on the development of large systems, proven technology and products are used.

Research has focussed almost exclusively on three South East Asian countries, Singapore, Malaysia and Indonesia. At the time of writing these countries all had fast-growing economies, but are at different levels of development in terms of technological infrastructure. Singapore is one of the most highly computerised countries in the world with a well-educated work force, Indonesia, on the other hand, is only just beginning on the implementation of large information systems. Malaysia falls midway between these two, and is still advancing very quickly through projects such as the 'Multi-media Super Corridor' which aims to attract the world's leading IT companies to Malaysia.

1.10 Organisation of the Document

This dissertation is structured as follows:

1. **Introduction**
   The rationale for the thesis. The problem to be addressed is presented together with the hypothesis offered as the basis for a solution. The research method and the initial assumptions are discussed. Finally background material is given with an outline of the thesis.
2. **Systems Theory**
   The philosophical foundation of the thesis is explained before going on to discuss the origins and development of Systems Theory as an explanation of the behaviour and characteristics of complex organisms.
3. **Organisations as Systems**
   A review of literature on the application of systems theory to social organisations, together with an outline of the relevance of this information to the development of computer systems.

4. **Corporate Information Systems**

   An outline of the development of computer systems, and the effect of this history on the integration of the computer system with the organisation.

5. **Organisational Analysis and Modelling**

   Systems theory is used to develop a business model which can be used to describe the business processes performed by the organisation. The information necessary to build the model is examined.

6. **The Development Environment**

   The organisational and technical environment in which system development takes place is analysed. The motivation of the various stakeholders is analysed, and the structure of a project team is proposed.

7. **The Development Process - Planning**

   The development process is divided into three main sections, covered in Chapters 8 - 10. The process is decomposed into tasks, each of which is viewed from the perspective of the various stakeholders

8. **The Development Process - System Design**

9. **The Development Process - System Implementation**

10. **Case Studies**

    Three large GIS systems, two successful and one less successful, are set out, compared, and analysed to determine the reasons for success and failure.

11. **Conclusion**

    The lessons to be learnt from this study are summarised.

2. SYSTEMS THEORY

The word "system" is defined in Collins International Dictionary as:

"a group or combination of interrelated, interdependent, or interacting elements forming a collective entity; a methodical or co-ordinated assemblage of parts, facts, concepts etc.".

Flood (1991 p.7) elaborates as follows:
"A system consists of a number of elements and the relationships between the elements. A richly interactive group of elements can be separated from those in which few and/or weak interactions occur. This can be achieved by drawing a boundary around the richly interactive group. The system identified by the boundary will have inputs which may be physical or abstract. The system does the work of transforming inputs into outputs. The processes in the system are characterised by feedback, whereby the behaviour of one element may feed back, either directly from another element by way of their relationship, or indirectly by way of a series of connected elements, to influence the element that initiated the behaviour. The system is termed an open system if the boundary is permeable and allows inputs from and outputs to the environment." This is illustrated in Figure 2-1 below.

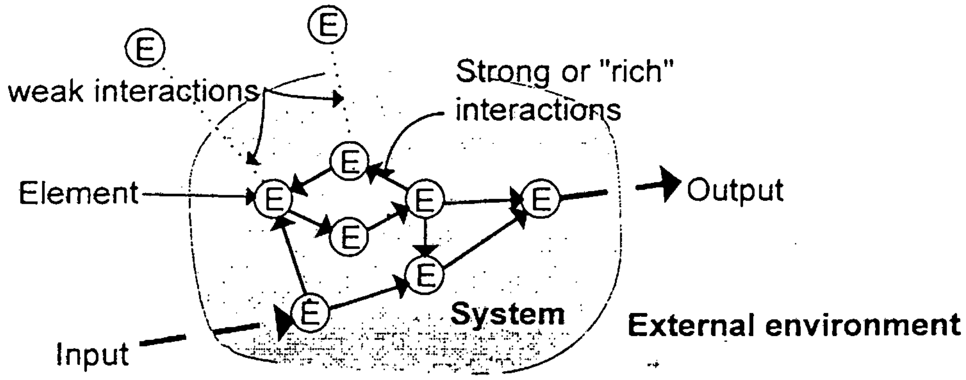


Figure 2-1 A System

2.1 The Philosophical Basis

In order to explain the approach taken here to systems, it is necessary to explain the underlying philosophical position adopted.

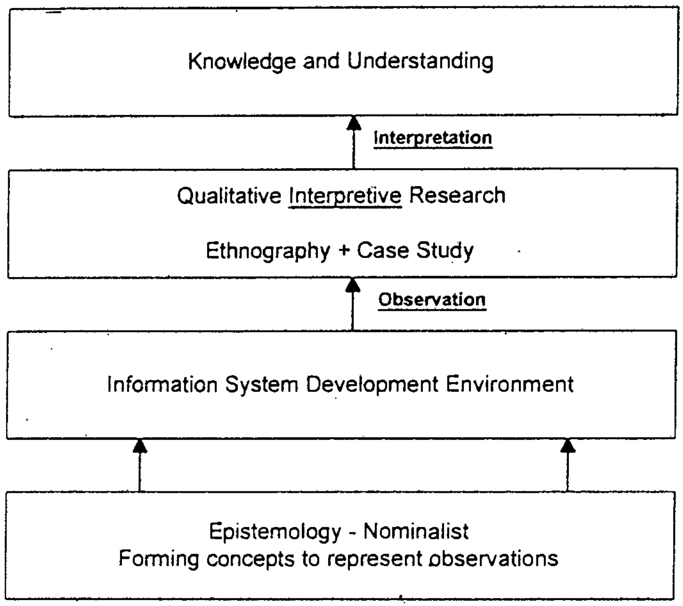


Figure 2-2 Philosophical Perspective

Figure 2-2 above illustrates the perspective adopted. Starting from a moderate nominalist position, the Information System Development Environment which is primarily a social organisation, is observed. The tools are ethnographic studies and case studies. Through interpretation of observations one arrives at knowledge and understanding of the development process.

2.1.1 Epistemology

It is generally accepted that knowledge is the object of research. We carry out research in order to obtain understanding of a particular topic, and thereby to gain knowledge. But what is knowledge? The theory of knowledge or *epistemology* is the branch of philosophy which attempts to answer this question. It is a question which has been debated by philosophers since the dawn of history, yet without any final conclusion being reached. It is a meta-physical question which many philosophers believe cannot be answered from our observation position in, and as part of, the world we are trying to understand. In the words of St.Paul "*Now we are seeing a dim reflection in a mirror; but then we shall be seeing face to face. The knowledge that I have now is imperfect; but then I shall know as fully as I am known*" (I Corinthians 13 v.12)

Before considering what knowledge is, we have to understand what the object of our knowledge is. It is at this point that the divide between realists and nominalists takes place. In broad terms the realists following Plato, believe that the world around us which we perceive through our senses, is a 'reflection' of an ultimate reality where 'universals', or ideal forms of familiar objects exist. Nominalists, in contrast, believe that the only knowledge of the world is gained through our senses, and that this knowledge is the order or classification imposed on our observations by our minds. In other words the thoughts and concepts which we use to think about reality are properties of our minds and result from the decisions we make in classifying them.

Traditional scientific thinking has favoured the nominalist position, but recent advances in linguistic analysis, especially by Chomsky and his followers, have shown that the basic structure of language is innate, that is to say, the way we use language to create ideas and concepts is constrained by the physical nature of our brains. Further constraints are provided by the three-dimensional physical world we inhabit. We can create a four dimensional hyper-cube in mathematical terms, but no-one can imagine or picture its appearance.

Both nominalist and realist views appear to have a certain element of truth. Tests on colour perception amongst people of different cultures with different languages show that they appear to see colour in the same way and to draw boundaries between colours in the same places. From this Rosch was drawn to the conclusion that the physical response of the light sensors in our eyes constrains mental classification of colour, and hence, that ideas of colour represent an underlying reality. This finding "*has fostered a revolution in the way we conceptualise concepts*"(Gardner 1985). Nevertheless, different cultures do tend to view natural phenomena in very different ways. Each culture has created a conceptual model to reflect its environment. This seems to support the nominalist point of view because different cultures use very different concepts to explain the same phenomena. In this case our concepts seem to be constructions of our minds which are not real in so far as they can be replaced by other concepts which serve the same purpose.

The view adopted here is that we acquire information about the physical world through observation and experience via our physical senses. In order to form a coherent world out of the mass of sensory information being received, our minds categorise the information in a framework which combines elements of hierarchy and network. The way this is done is an intrinsic function of our innate language ability.

We are also *rational* beings. Our nature requires that the framework we construct be internally consistent. This theory is set out in (Walker 1990). When facts contradict our assumptions, we react in various ways including denial, invocation of the supernatural, mental illness, or the adoption of a new mental framework - the so-called paradigm change. In this sense *rational* does not mean that our belief can be proved using Aristotelian logic from a set of *a priori* assumptions. It means that we are led to a particular belief by a myriad of observations and environmental and cultural factors which are all weighed up and considered.

Quine is an exponent of this point of view. Scruton summarises his argument in the following terms: "*All we can say, is that our language forms a single system or 'conceptual scheme', which faces the 'tribunal of experience' as a whole. We have no need to refer to meanings - ghostly meta-physical entities whose conditions of identity can never be defined. For the dimension of sense is not required in order to relate our language to the world: reference alone suffices. And when we consider our conceptual scheme as a whole, we see that there is no distinction that we could possibly make between those items in it that are necessarily true, and those that are merely contingent. The only distinction that we could make (and the only one that we need to make) is between sentences that we are reluctant to give up in the face of recalcitrant experience, and the sentences which can be jettisoned without compunction. This distinction is a distinction of attitude, it does not describe 'two ways of being' in the world*".

2.2 How do we categorise knowledge?

Ontology (ων present participle of ειναι - to be) means the theory of <u>being</u> or existence in classical philosophy. Recent definitions include:

> *An ontology is an explicit specification of a conceptualisation.* (Gruber 1994)
>
> *An ontology is a theory of what entities can exist in the mind of a knowledgeable agent.* (Wielinga 1993)
>
> *An ontology for a body of knowledge concerning a particular task or domain describes a taxonomy of concepts for that task or domain that define the semantic interpretation of the knowledge.* (Alberts 1993)
>
> *...we want not only an account of what exists, but also an account of the structure of what exists. This structure is implied in the language we use: this is the reason why the term "ontology" is often used as a synonym of "terminology" in the AI community.* (Guarino 1997)

These definitions are rather distant from the classical meaning of ontology. The common thread in the definitions above is classification of ideas and concepts. This, in turn, may perhaps reflect a nominalist view of the world.

The idea of a mental framework of concepts begs the question 'What is a concept?' Guarino's answer is "*a set of informal rules that constrain the structure of a piece of reality, which an agent uses in order to isolate and organise relevant objects and relevant relations*". (Guarino 1997) The answer seems reasonable though the language is rather convoluted. One might say '*A concept it a set of rules used by an observer to relate observations to one another and <u>to his existing knowledge</u>.*' The last part is important because concepts are formed from what we know already, - hence mature students because of their wider knowledge of the world, often grasp concepts more quickly than young school-leavers.

2.3 How do we know what is true?

Following Plato, knowledge has been traditionally defined as 'justified true belief'. This begs Pilate's question "*Truth, what is that?*" (John 18 v.38) to which there is no definitive answer. The consensus amongst modern philosophers is that the concept of knowledge serves to enable us to distinguish reliable from unreliable beliefs. Scruton (p.323) writes "*...few philosophers* *doubt that reliability has won out over justification, as the best candidate for what is really meant by knowledge.*" Knowledge implies reliable beliefs, in other words beliefs in which we can place our trust to function in the world, pursuing careers and raising families. However, reliable beliefs may only be reliable in context. For example, in the everyday world Newton's Laws of Motion provide a reliable basis on which to build cars and aeroplanes and even to send rockets to the moon. By changing the context to sub-atomic particles moving close to the speed of light, the belief in Newton's Laws is rendered unreliable.

Thus knowledge, in most cases, isn't the truth, but approximates, in varying degrees, to the truth. With respect to the physical world, scientific theories may be viewed as nominalist constructions tending towards an unknown reality.

There are three traditional bases for judging truth: authority, reason and experience.

a) An epistemology based on **authority** states that truth is given to us by someone more knowledgeable than ourselves. The two primary variations of authority-based epistemologies are omniscient authority (the authority is God), and human authority (the authority is a human expert). Holloway writes "*In truth, I believe that the revelation that God has given in the Bible provides the only intellectually defensible fundamental epistemology*" but a majority of scholars would probably not agree with him. Weight should always be given to human authority but it is not infallible. Every major advance in knowledge has resulted in earlier authorities being overthrown.

b) An epistemology based on **reason** claims that what is true is that which can be proven using the rules of deductive logic.

   Can truth be approached through logic from an *a priori* position? Probably not, but traditional logic is not a help in this. Reason in Western logic has been linked to two values: true and false. If a proposition is not true, it is *ipso facto* false. This idea underpins Aristotelian logic which may be described as the cornerstone of Western thinking. However, this does not accord with reality where most things are grey rather than black and white. The problem was noted early this century by Russell who wrote "*Everything is vague to a* *degree you do not realise till you have tried to make it precise."*

In 1965, Zadeh published his paper "Fuzzy Sets" in the journal *Information and Control.* This was the first step towards a wider acceptance of the concept of vague, or fuzzy, logic.

All non-linear systems are essentially fuzzy. By trying to apply mechanical true/false logic to the analysis of such systems, unnecessary problems are created. By adopting a 'fuzzy' approach, not only is the understanding of non-linear systems facilitated, but practical applications related to such systems become more tractable. This approach is implicit in the writings of Checkland on 'soft systems'.

c) An epistemology based on **experience** claims that what is true is that which can be encountered through one or more of the senses. Several different variations of experience-based epistemologies exist. The two most relevant variations are anecdotal experience and experimental evidence. The first states that truth for any particular individual (or group of individuals) is that which the individual (or group) personally experiences. The second states that truth is that which can be verified through carefully controlled experiments.

The view adopted here is that information gained through experience, from human authorities, or derived from reason, is not 'truth' but information with varying degrees of reliability, which may approach the 'truth' to some degree.

Seventy years ago Smuts foreshadowed this change in thinking in the following passage:

The science of the nineteenth century was like its philosophy, its morals and its civilisation in general, distinguished by a certain hardness, primness and precise limitation and demarcation of ideas. Vagueness, indefinite and blurred outlines, anything savouring of mysticism, was abhorrent to that great age of limited exactitude. The rigid categories of physics were applied to the indefinite and hazy phenomena of life and mind. Concepts were in logic as well as in science narrowed down to their most luminous points, and the rest of their contents treated as non-existent. Situations were not seen as a whole of clear and vague *elements alike, but were analysed merely into their clear, outstanding, luminous points. A "cause," for instance, was not taken as a whole situation which at a certain stage insensibly passes into another situation, called the effect. No, the most outstanding feature in the first situation was isolated and abstracted and treated as the cause of the most outstanding and striking feature of the next situation, which was called the effect. Everything between this cause and this effect was blotted out, and the two sharp ideas or rather situations of cause and effect were made to confront each other in every case of causation like two opposing forces. This logic precision made it impossible to understand how the one passed into the other in actual causation.*

There is no way out of this impasse but to retrace our steps and see that these concepts are partial and misleading abstractions. We have to return to the fluidity and plasticity of nature and experience to find the concepts of reality. When we do this we find that round every luminous point in experience there is a gradual shading off into haziness and obscurity. A "concept" is not merely its clear luminous centre, but embraces a surrounding sphere of meaning or influence of smaller or larger dimensions, in which the luminosity tails off and grows fainter until it disappears. Similarly a "thing" is not merely that which presents itself as such in clearest definite outline, but this central area is surrounded by a zone of intuitions and influences which shades off into the region of the indefinite. The hard and abrupt corners of our ordinary conceptual system do not apply to reality.

The world is thus in abstraction constituted of entities that are discontinuous, with nothing between them to bridge the impassable gulfs, little or great, that separate them from each other. The world becomes to us a mere collection of disjecta membra, drained of all union of mutual relations, dead, barren, inactive, unintelligible. And in order once more to bring relations into this scrap heap of disconnected entities, the mind has to conjure up spirits, influences, forces and what not from the vast deep of its own imagination. All this is due to the initial mistake of enclosing things or ideas or persons in hard contours which are purely artificial and not in accordance with the natural shading-off continuities which are or should be well known to science and philosophy alike." (Smuts J C, Evolution and Holism, 1926)

Dealing with the *sorites* paradox, Scruton writes "*Maybe we should speak instead of degrees of truth, and say that, as we heap grains of sand on to the* *pile, it becomes more and more true that the collection is a heap...Some however argue that the price of the solution is too great to pay. We can no longer assume, they suggest, the validity of modus ponens, since this is defined only of propositions with absolute truth-values; nor can we assume the tenability of classical logic, which is likewise built up on an absolute conception of truth. ...a solution may oblige us to acknowledge that everyday reasoning is very different in structure from the reasoning that occurs in mathematics."*

In the context of this thesis, the goal is to seek reliable facts about information system development in order to develop beliefs which, when applied in the relevant system development context, will enable systems to be developed which do what their designers intended. The observations and facts collected and assembled here will not lead to an objective 'truth', indeed they cannot; but they do enable a practical working framework to be developed.

2.4 Systems Thinking

As mentioned in the introduction, the reductionist approach of *scientific method* has been extremely successful in explaining the world we live in, and in creating a theoretical framework which has made the unparalleled technological progress of the present era possible. One result of *scientific method* has been the creation of a hierarchy of scientific disciplines. Physics, at the most basic level, deals with the fundamental forces and particles making up and holding the universe together. The various elements and compounds which comprise the visible world are all formed from atomic particles such as electrons, neutrons, protons etc. which are grouped together in different ways. These elements and compounds have widely differing properties which could not be predicted from a study of the elementary particles - hence the discipline of chemistry. In the same way the physiology of living creatures cannot be predicted from a knowledge of the constituent elements; biologists specialise in this area. In other words <u>the behaviour of more complex systems cannot be predicted from a study of the different components which constitute the complex system</u>. This fact was recognised by many writers including Smuts (1926 p.104), who wrote "*The combination of the elements into this structure* (system) *is in a sense creative, that is to say, creative of new structure and new properties and functions.*" i.e.

the system has new properties which cannot be discovered by studying the constituent parts.

Eventually a reaction took place against reductionism. Systems thinking began in the 1920's with writings by Smuts and others. Ludwig von Bertalanffy, a biologist, pointed out that metabolism, the unique feature of living creatures, occurs only within highly organised structures. This thought led him, in due course, to develop a general theory of systems.

2.5 General Systems Theory

In 1951 von Bertalanffy described 'open systems' or self-maintaining structures in anatomical terms. He suggested that the human being, for example, could be regarded as an open system in that it maintains its structure (body temperature, circulation, digestion, respiration etc.) in a changing environment - hot, cold, wet, dry, urban, rural. The human being in turn, is made up of numerous sub-systems such as the skeletal, circulatory, digestive, hormonal, reproductive and sensory systems. Bertalanffy extended this analogy to the scientific field to study the relationships between specialists in different fields, and hence, to obtain a better understanding of large systems.

The study of an ecological system for example, needs botanists and zoologists to study the flora and fauna, anthropologists to study the interaction between man and the environment, as well as climatologists and meteorologists to study the climate and weather. Information technologists are needed to design data models and storage systems, and to analyse the data. Since all the data has a spatial component, a specialist in spatial information systems is needed too. Problems arise because each of these specialists has his own technical language hampering communication. Communication is absolutely essential in order to build up an accurate picture of the whole ecological system.

Bertalanffy's ideas were taken up by Kenneth Boulding and others who formed the Society for General System Theory in 1954 (Schoder 1981). The aim of the Society was to foster communication between scientists from different disciplines in order to facilitate the sharing of knowledge and to minimise the duplication of scientific research (see Kroeber 1990 pp.30 - 37). Boulding (1956 p.197) defined General Systems Theory as "*a name which has come into use to* *describe a level of theoretical model building which lies somewhere between the highly generalised constructions of pure mathematics and the specific theories of the specialised disciplines....*

In recent years increasing need has been felt for a body of systematic theoretical construction which will discuss the general relationships of the empirical world. This is the quest of General Systems Theory. It does not seek, of course, to establish a single, self contained "general theory of practically everything" which will replace all special theories of special disciplines. Such a theory would be almost without content, for we always pay for generality by sacrificing content, and all we can say about practically everything is almost nothing. Somewhere however between the specific that has no meaning and the general that has no content there must be, for each purpose and at each level of abstraction, an optimum degree of generality."

Klir (1969 p.vii) lays down requirements for a valid General Systems Theory which include the following:

- *The theory must be based on precisely defined concepts. Vague concepts are not accepted.*
- *There must be no limitation in the application of the theory with the exception of systems with an infinite number of quantities or an infinite number of elements. More specifically, the theory must be applicable in experimental sciences, engineering, and the social sciences.* (In other words, is the theory applicable to the behaviour of both computer and human systems?)
- *The theory must be applicable for both the description of the system properties and the solution of system problems, i.e. both descriptional and operational views must be applicable.* That is to say, the theory should not only explain why a system behaved in a particular way in the past, but should also predict how the system will behave in response to a given set of inputs in the future. Where social systems are concerned this is no easy matter. Economic theory for instance, is generally much better at explaining why the economy behaved as it did (with hindsight), than at predicting how it will behave in future.

Systems theorists have addressed the unpredictable behaviour of societies by invoking the concept of *chaos*. Stable systems operate within defined parameters. If the parameters are varied, there comes a point where the system's homeostatic regulator breaks down. It is postulated that societies, particularly those undergoing rapid change, operate in the boundary region where very small changes in input can produce unpredictable results. It is this environment which enables individuals or small groups to change the course of history. Such historic discontinuities as the rise of Islam or Christianity cannot be explained by a study of the societies in which Christ or Mohammed lived.

Several recent writers on management suggest that innovative and successful companies operate in the chaotic region, but that within this region of chaos patterns do recur and can be recognised and used.

2.5.1 Hierarchy of Systems

Boulding proposed categorising all areas of scientific interest within a hierarchy of systems ranging from the basic framework of matter to transcendental systems. Boulding's (1956) hierarchy comprises nine levels, viz.

1) Static structures and frameworks.
2) Simple dynamic systems with pre-determined motions e.g. clockwork.
3) Control or self-regulating systems, e.g. **computer systems**.
4) The self-maintaining or "open" system, e.g. the single cell, the beginning of life.
5) Plant systems characterised by complex arrangements of cells without mobility or self-awareness.
6) Animal systems characterised by mobility and self-awareness.
7) The human as a system, characterised by self-awareness, language and communication.
8) Human social organisation, including emotions, value systems, and art. The computer-based information system is a hybrid between computers (control systems) and human organisation. As such it inherits all the complexity of the human social organisation.
9) Transcendental systems encompassing the ultimate and absolutes, e.g. religion and theology.

Writing of this classification, Checkland (1981, p.104) asks "*Is it convincing and does it help resolve any problems?*". He concludes that it is indeed convincing, so much so that no dissenting voices are raised. However, he finds it disturbing that we still have no idea of the scale of system complexity which everyone finds so convincing.

2.5.2 Characteristics of Systems

According to Boulding, all systems share certain common characteristics:

- systems are goal-oriented
- systems convert inputs into outputs
- systems are holistic
- systems are differentiated
- systems are hierarchical
- systems are inter-disciplinary
- systems are synergistic
- systems must be maintained

Systems are goal-oriented

Implicit to every open system is the primary long-term goal of maintaining its own existence; the system also has a more concrete short-term goal or goals. For example, the Inland Revenue Department has the goal of collecting all the taxes levied by the government, while the Mapping Department has the goal of producing high-quality maps to meet the needs of developers, administrators, tourists etc. Nevertheless, there are numerous examples of organisations changing their (short term) goals in order to continue to function; in other words, falling back on the implicit goal of self-preservation.

It must also be recognised that open systems have a life cycle. Organisations go through a period of growth when new staff are employed and new goals adopted. Later there is a period of stable existence which eventually leads to decline. Some organisations are created to accomplish a special purpose and dissolved when this purpose has been achieved e.g. a constitutional assembly. While these organisations are progressing towards their goals they behave as open systems.

Firms often diversify into other areas of business when their primary business declines. The Nautical Department at the Singapore Polytechnic provides an interesting illustration. The function of this department was to train deck officers for the Singapore merchant navy. A reduced demand for mariners led to a sharp fall in the student intake. This in turn threatened the department with closure. The department responded to this threat, initially by introducing shipping-related business courses, and subsequently by transforming itself within three years into a fully-fledged business administration department.

Systems convert inputs into outputs

The primary reason for studying systems is to analyse how inputs are converted to outputs, and how the process can be made more efficient in order to increase productivity. Some inputs are very obvious - for example manufacturing organisations use raw materials such as steel, plastic and wood to produce manufactured goods as output. **Information** is also a major resource of **every** organisation. Without information the organisation is cut off from its environment and is not able to function. Wessel (1979, p.2) writes "*Information, its flow and control lie at the heart of things.*".

Systems are holistic

Systems do not exist in isolation. GIS interacts with other computer systems such as accounts, personnel, sales etc. If the interfaces between the different systems are to function properly, a global or holistic view must be taken in the system design stage. Critics of the systems approach to organisation theory seize on this property in an attempt to show that the systems approach will of necessity lead to a centralised organisation. However, this is not so. The balance of power between the centre and the various component sub-systems is a complex matter influenced by a variety of factors such as the capacity of the internal communication channels, the technical skills available in the sub-systems, and the organisational cohesion produced by the presence of a common goal. The tension between the centre and the parts is reflected in tension between central and regional governments in large countries, and between the head office and regional offices in large multi-national companies.

However, it must be recognised that a society, in contrast to a collection of individuals, must have a decision-making capability and the power to enforce its decisions.

Systems are differentiated

Every system can be broken down into a number of sub-systems. The nation comprises government departments, quasi-government organisations and private companies. Each of these organisations is made up of individuals who in turn comprise brains, circulatory systems, digestive systems etc. Each of these sub-systems can be repeatedly broken down to atomic or even sub-atomic level. Computer-based information systems comprise a number of sub-systems, for example, systems for accounts, stock control, payroll, personnel, mapping, planning etc. Geographic information systems are made up of sub-systems for data capture by photogrammetry, scanning, digitising etc. for system maintenance and updating, for application development to generate the necessary reports and maps and for staff training, etc. Each sub-system has its own function clearly differentiated from that of others.

If two sub-systems are not clearly differentiated, in other words, if they have similar goals and responsibilities, friction will develop between them. The only way in which this problem can be resolved is either by absorbing one sub-system into the other, or by clearly defining and differentiating the functions of each.

Systems are inter-disciplinary

This is implicit in the fact that the systems movement arose in reaction to the reductionism of scientific method. Because systems comprise differentiated sub-systems carrying out specialised functions, the services of specialists in different areas are needed. In the body a host of organic compounds perform specialised tasks, for example, haemoglobin has the specialised role of carrying oxygen to the brain and muscles, while bile digests food. In a geographic information system, computer hardware engineers are needed to keep the computers and peripherals running, system and application software specialists keep the system operating correctly, while land surveyors, geographers, town planners, engineers, environmental scientists, geologists etc. decide how the data should be structured, manipulated and presented in order to meet their professional requirements. As will be shown later, cohesion and control are maintained in organisations by communication between sub-systems. Specialists in different areas lack a common professional background. Without good communications this can easily lead to misunderstandings resulting in sub-optimal system performance.

Systems are hierarchical

Systems are hierarchical in the sense that most systems are sub-systems of a super-system on the one hand, and are themselves super-systems of a number of sub-systems. For example, the individual contains a number of mental and physical sub-systems. He is, in turn, a sub-system of his company. Social systems are seldom purely hierarchical, because the individual often forms a part of a number of systems. He is not only a sub-system of his firm, but also of his church, sports club etc. In fact Beer (1984) states "..*purely hierarchical models of management are useful for little more than apportioning blame,..*", but goes on to say "*every viable system contains and is contained in a viable system*". This he terms the **central principle of recursion.** This holds true as long as long as the focus is on a single super-system, but in reality the hierarchy is combined with a networked overlapping structure as shown in Figure 2-3 below.

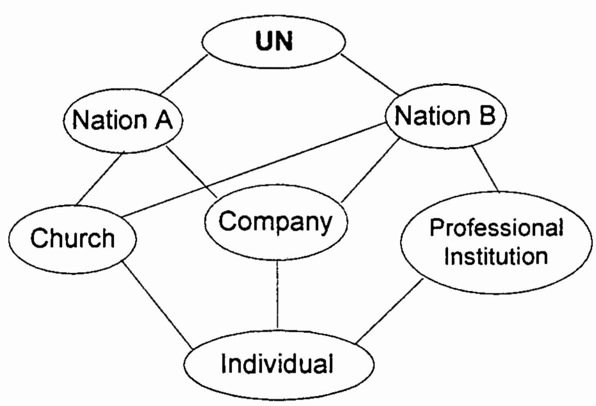


Figure 2-3 A Networked Hierarchy of Systems

Extending the principle of recursion to the computer-based information system, the various components of the computer system may be seen as systems in their own right, each one a sub-system of the computer-based information system (CBIS). The CBIS for its part, is a sub-system of the organisation. The latter point is very important because this is where the man/machine interface occurs, and where most implementation problems arise.

The hierarchical structure is illustrated below in Figure 2-4 below. It shows a typical computer-based information system. While there is a clearly defined hierarchy, there are also links between sub-systems.

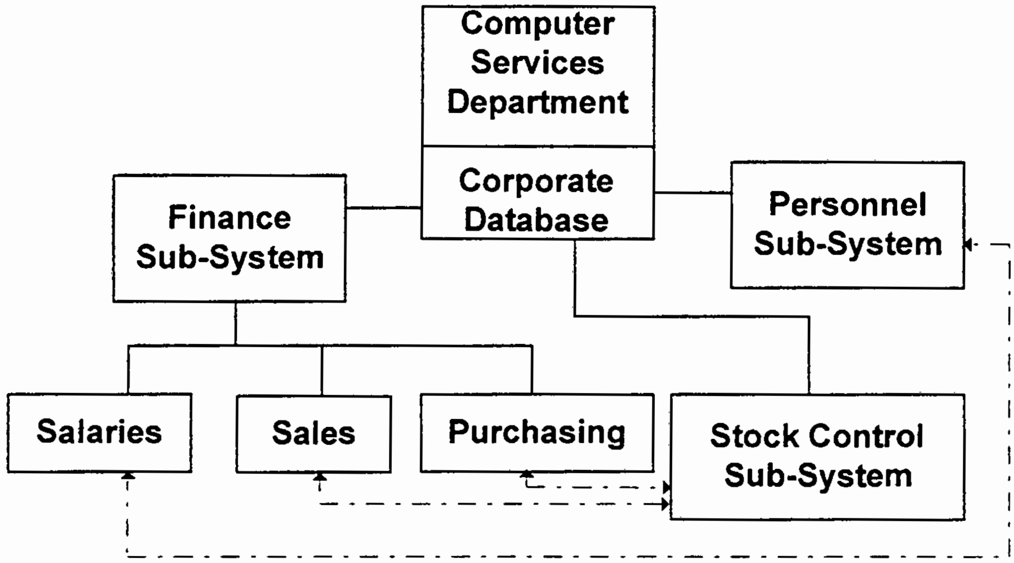


Figure 2-4 A Typical Computer-based Information System

Systems are synergistic

"The whole is greater than the sum of the parts". "*There are properties relating to the whole system but not necessarily present in any of the parts*" (Flood 1991, p.10). It is synergistic gains which lead to specialisation and co-operation. Free trade allows each nation to specialise i.e. to concentrate on what it does best, and to buy from others goods which they can produce more efficiently, hence the freer the trading system, the greater the overall prosperity. This does not necessarily result in greater prosperity for every sub-system, hence the lobbying against free trade by special interest groups everywhere.

The value of the various components of a geographic information system are enhanced by bringing them together in a system. An automatic mapping system can be created by combining a data capture unit with a plotting unit. This system will achieve substantial productivity gains by automating the traditional system of map production. However, by adding a database management and analysis unit, it is at once possible to combine different data sets and present data in alternative ways, greatly enhancing the value of the data. Further value may be added by supplying office administration functions such as electronic mail, document imaging and word processing. The integrated whole is far more valuable than the sum of the individual components.

Systems must be maintained

Isolated systems tend towards maximum entropy or disorder (Second Law of Thermodynamics). This principle applies to physical systems but may be extended by analogy to organisational systems. A geographic information system which is not undergoing continual modification and upgrading will become less and less useful to users and will eventually 'die' i.e. it will be used less and less because performance and user-friendliness are not keeping up with current developments and because the data becomes less useful the more out-of-date it gets. Similarly an organisation which is not interacting with the external environment soon becomes irrelevant to the environment and becomes 'fossilised' or disappears.

Open (or viable) systems maintain their **dynamic equilibrium** (or **homeostasis**, as Flood (1991 p.10) calls it) through interaction with the environment, or the import of negative entropy. For example, if the spatial data does not reflect current reality, action is initiated to revise the data. A successful information system is continually receiving new or amended data, supplying data to users, absorbing new techniques and new technology, and undergoing development. It does this in order to remain relevant to increasingly sophisticated users. This seldom happens by chance. The system design must address on-going system and data maintenance and <u>the necessary organisational structure must be set up in the implementation stage</u>.

2.6 Communication

It is obvious that it is communication which ties different sub-systems together and allows them to work harmoniously as a system. When communication is poor, the sub-systems either wither and die, or strike out on their own as independent systems. Communication is absolutely central to the whole system concept. In mechanical systems the various sub-systems communicate through mechanical links such as cogs and gear wheels. In living organisms, chemical messengers are used. Computer systems use the flow of electrons to carry messages. In social organisations, language, both written and spoken, provides the primary means of communication.

The study of cybernetics or control systems led Norbert Wiener (1948) to conclude that every system is held together by means for acquiring, using, retaining and transmitting information, that is to say, communication and data storage.

Claude Shannon (1949) built on Wiener's work and is generally credited with establishing the foundations of information or communication theory. This theory is relatively narrow in concept and applies primarily in the technical field of data communication.

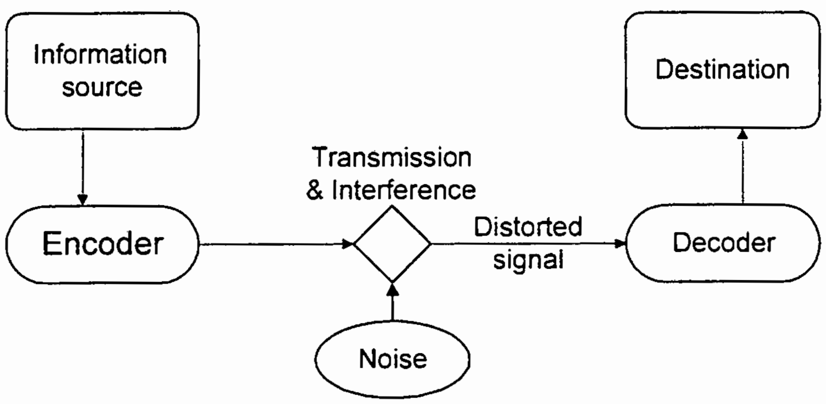


Figure 2-5 A Simple Communication Model

Figure 2-5 shows the basic layout of a communication system.

Before transmission, the information must be encoded into the format required by the communication channel. For example, words have to be converted to electronic impulses to travel on telephone cables. Similarly, the received signal must be 'decoded' before it can be understood. This is the inverse of the original encoding process. In a perfect world this would produce an exact copy of the original message at the destination. Unfortunately the world is not perfect and there are many sources of distortion or 'noise' which intervene to corrupt the original message. Moreover, the encoder and decoder are seldom perfect.

The term 'noise' is used to mean any external factor which interferes with, distorts, or even swamps the message. In the above example, physical noise would interfere with successful transmission of the message by preventing the listener from hearing the message correctly, but 'noise' might also be electronic distortion caused by random electro-magnetic fields. Such noise can make a fax message illegible, or corrupt electronic data. However, by transmitting redundant data i.e. more data than is necessary to convey the message, it becomes possible to correct a certain number of errors. For example, the common ASCII code used to encode text for data transmission, uses 8 binary digits (bits) to encode one character. In other words, the code could represent 256 distinct characters. However, the upper and lower case letters, numerals and punctuation comprise less than 128 characters. Consequently the eighth bit is redundant and can be used as a check on the data. This is the 'parity' check widely used in digital computers.

In communication theory, the **information** content of a message is defined as the average number of binary digits which must be sent to identify the message from the set of all possible messages to which it belongs. If the set of all possible messages contains n messages, then the information content of each message is I where $I = \log_2 n$. From this it follows that a message of infinite length would be needed to transmit any particular message out of a universe comprising an infinite number of messages. Nevertheless, effective communication occurs all the time within an apparently infinite universe. This is possible because finite sets of messages are used for communication.

At the level of organisms, communication depends on the presence or absence of a particular chemical. Each messenger has a specific 'receiver' or receptor. The receptor can behave in two ways according to whether it received its specific message or not. This is a binary communication system. The set of all possible messages contains two messages - the presence of chemical 'x' or its absence. Communication within computer systems too, is built on a binary relationship - either the presence or absence of an electron at a particular detector.

Communication is not instantaneous. From a human perspective, electronic data transmission may appear so, but at the speed at which today's computers operate, the delays introduced by the distance separating the different parts of a computer must be taken into account by hardware designers. People handle data much more slowly. We cannot increase the speed at which we speak very much without becoming unintelligible. Even 'speed' readers cannot process much more than 1000 words per minute, while ordinary readers handle about 250 words a minute. Computers can produce large quantities of printed information very quickly, in fact far more quickly than the information can be read. This phenomenon has given rise to the expression '**information overload**'. In other words people in the modern commercial and administrative environment are being bombarded by more information than they can read and digest. In this situation the natural reaction is to 'switch off' and to ignore all the incoming information.

Stafford Beer (1979, p.99) points out in his *'Second Principle of Organisation'* that each communication channel *"must have a higher capacity to transmit a given amount of information relevant to variety selection in a given time than the originating sub-system has to generate it in that time."* Today, almost twenty years later, when information includes sound and video, channel capacity, or band-width, is still a limiting factor in communications.

2.7 Control in Systems

One of the characteristics of a system is that it is goal-oriented. In order to advance towards a goal, it is necessary to check one's position once in a while to see if one is still on course, and, if not, to correct the course. This *monitoring* and *correcting* is the essence of control.

A control system comprises four components as shown in Figure 2-6 overleaf :

- The system being controlled
- The sensor monitoring the condition to be controlled
- The control unit
- The activating unit

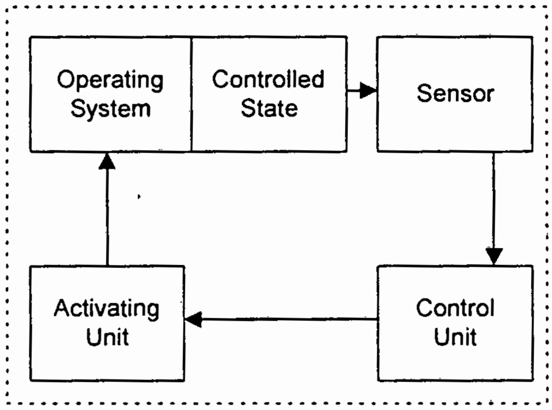


Figure 2-6 A Generic Control System

A ship's autopilot provides an example of a simple control system. The course of the ship is monitored by a compass. The control unit compares the compass reading with the pre-set course. If the result is outside the allowable limits, the activating unit moves the helm in such a way as to correct the course. It is clear that if the correction to the helm is maintained until the ship is again on course, the ship will continue swinging well off to the other side of the true course. Hence a practical system must also monitor the rate of change of course and compute when to return the helm to amidships so that the inertia of the ship will swing it just back to the true course. This observation led Stafford Beer (1979, pp.69-71) to postulate an "Adjuster Organiser" as a metasystem describing the system being controlled, and as a learning device which adjusts the control unit on the basis of past experience.

The same control mechanisms operate in social systems or organisations. The difference is that humans are often unpredictable, irrational and emotional. Their behaviour in any circumstance cannot be predicted with certainty. Figure 2-7 below typifies a control system in a commercial organisation.

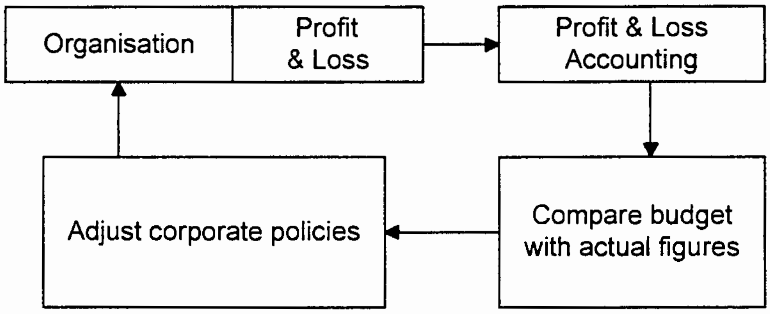


Figure 2-7 A Commercial Control System

2.8 Open Systems

An **open system** is one which interacts freely with its environment and has the ability to adapt to changes in the environment, so as to maintain itself.

At this point a caution is necessary. No system can be either completely closed or completely open. With regard to classifying systems as 'open' or 'closed' Stafford Beer (1979, p.260) writes *"I do not find these categories helpful, since I cannot identify any system that is either completely open or totally closed."*

Biological and social systems are generally classed as 'open systems', so naturally considerable research has been done through systems modelling to discover the principles on which such open systems operate. One such model is the **viable system model** which applies particularly to social systems, and is derived by analogy with physiological systems i.e. the neuro-cybernetic model. This model will be considered in more detail below.

2.8.1 Viable Systems

Stafford Beer (1979, p.405) describes a viable system as a system which produces itself. *"The enterprise, that arbitrary whole, produces itself too. That is to say that its staff may come and go, its departments may be closed down or opened up, it may be nationalised or denationalised - and still it has and retains its* ***identity.***

In cybernetic terminology, this enterprise is called autopoietic. The word derives from the Greek: ποιω *meaning 'I make'. So an autopoietic system makes itself - continuously. What business is it in? It is in the business of* ***preserving its own organisation.****"*

From the late 1950's onward, Stafford Beer has developed the **Viable System Model** or VSM in order to identify the components comprising a viable system and the necessary conditions for it to remain viable. Beer (1984) states *"the management of any viable system poses the problem of managing complexity itself, since it is complexity (however generated) that threatens to overwhelm the system's regulators."* Beer's model flows from the need to understand how viable (as opposed to moribund) systems handle complexity. In order to define exactly what is meant by *complexity,* the term **variety** has been introduced. Ashby (1957 p.126) defines the variety of a system as the number of distinguishable elements in the system, or by extension, the number of possible system states.

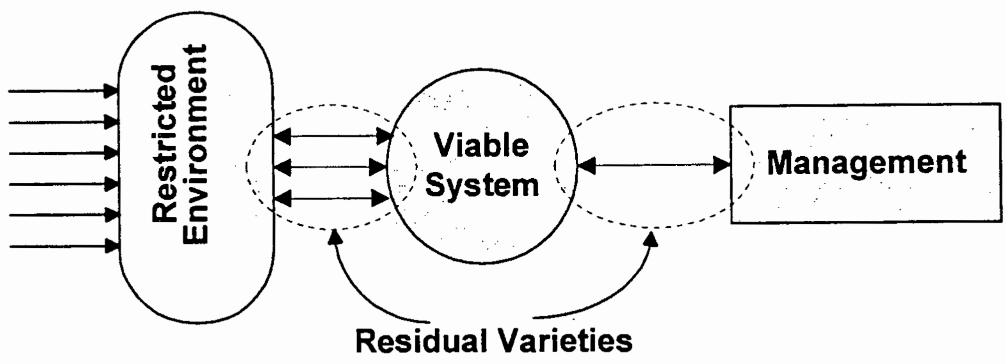


Figure 2-8 The Attenuation of Variety

We know intuitively that humans are not able to cope with great complexity. Analogies, metaphors and models are used to present a problem in a more simple way, i.e. the high variety of the external environment is filtered by the model or analogy to reduce variety to a level we can handle. It is then possible to test whether a solution developed on the model will work in the real world situation. The better the model, the more likely it is that the solution will work. Figures 2-8 and 2-9 illustrate a system being overwhelmed by variety, and the use of filters to reduce that variety.

Within any viable system the same problem arises - that of matching high variety inputs to a low variety control system. Beer's First Principle of Organisation (1979, p.97) states "*Managerial, operational and environmental varieties, diffusing through an institutional system, tend to equate; they should be designed to do so with minimum damage to people and to cost*".

Raul Espejo has raised the question of how these varieties can equate when they are clearly of different magnitudes. He answers this by suggesting that the system operates within a restricted external environment, e.g. a network of car dealers for a car manufacturer, and that this limited environment plays a role in attenuating the varieties reaching the system. Only a limited number of varieties, called residual varieties, are passed on to the system. The system in turn attenuates the varieties transmitted to the management. This has led Espejo (1989) to formulate the First Principle in a slightly different way: "*The response varieties of a viable system and its management tend to equate, respectively, the residual varieties of the environment and operations; they should be designed to do so with a minimum damage to people and to cost*".

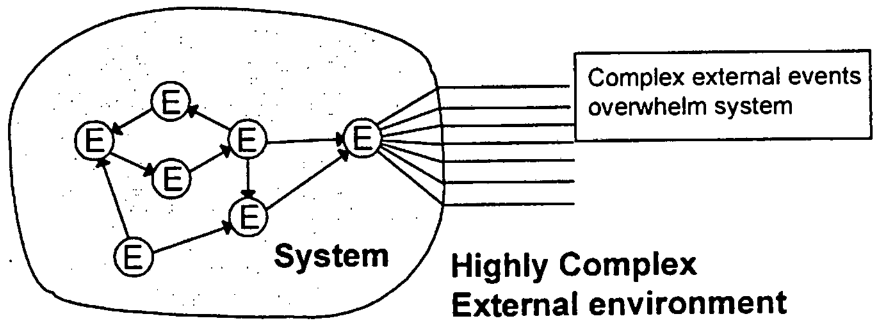


Figure 2-9 A Filter is Required to Reduce the High Variety in the External Environment

In Beer's model every viable system is composed of five sub-systems connected by information and control channels. These are illustrated in Figure 2-10 overleaf.

Beer refers to the system by number:

1 Operations
2 Co-ordination
3 Control and Monitoring
4 Intelligence
5 Policy

System 1 is the sub-system which realises the system's goal, while sub-systems 2 - 5 form a metasystem which controls sub-system 1 and make the necessary responses to ensure that the system remains viable when changes in the environment occur.

The super-system containing the system under study is sometimes referred to a 'meta-system'. This is because the five sub-systems do not necessarily exist as organisational units, and the same individual may perform the functions of one sub-system at one time, and the functions of another sub-system at another time. In diagnosing organisational problems, the skills of the consultant are needed to identify which groups or individuals perform which roles, because this cannot be discovered by studying organisational charts.

System 1 activities form a recursive hierarchy. System 1 may contain one or more groups of sub-systems, each complete with Type 1 to Type 5 functions.

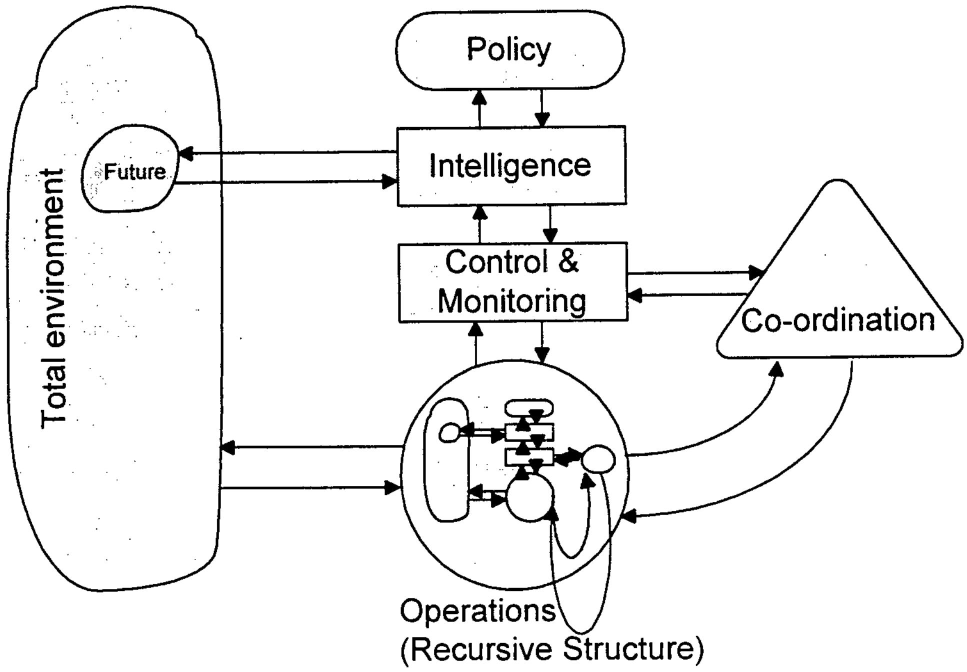


Figure 2-10 Outline of the Viable System Model

The types of functions performed by each system are

1 Operations
2 Co-ordination
3 Control
4 Intelligence & Planning
5 Decision making

Beer sees the function of System 2 as anti-oscillatory, damping large swings in output from various System 1 operations. He writes (1979, p.177) "*System Two is logically necessary to any viable system, since without it System One would be unstable - would go into an uncontrollable oscillation*". He uses as an example control of production - the number of semi-finished articles produced by one sub-system must match the demand of the sub-system which uses these articles. System 2 also achieves co-ordination by specifying the interfaces between sub-systems, and by specifying how processes will be performed. In Beer's neuro-cybernetic analogy, System 2 corresponds to the human autonomous nervous system. Most system inputs are handled automatically by System 2 without involving System 5 decision making. In other words, this system absorbs most of the variety in System 1. For example, an estates officer in the British Defence Lands Office has a ten volume manual of procedures. These lay down precisely the limits of his authority and responsibility, and how each of hundreds of different cases should be handled. Only cases not covered by the manual need to be referred to a higher-level decision-maker.

Beer writes that he arrived at his concept of the viable system as a result of his time as a National Serviceman in the British Army. It is not surprising therefore to find a close correspondence between the viable system model and the almost universal military hierarchy. This is shown in Figure 2-11 below.

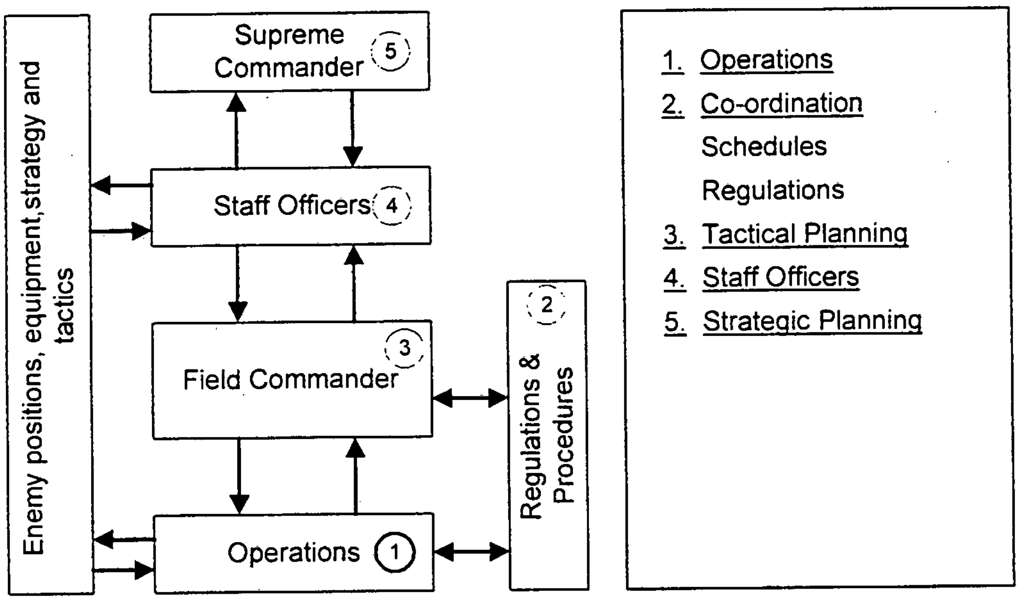


Figure 2-11 The Army as a Viable System

Although the computer is essentially a mechanical system, with the appropriate programs, it may display features of a viable system in so far as it can adapt to changes in the external environment. In Figure 2-12 overleaf the viable system model is applied to a typical computer system.

The different parts of the operating system perform the roles of control and policy.

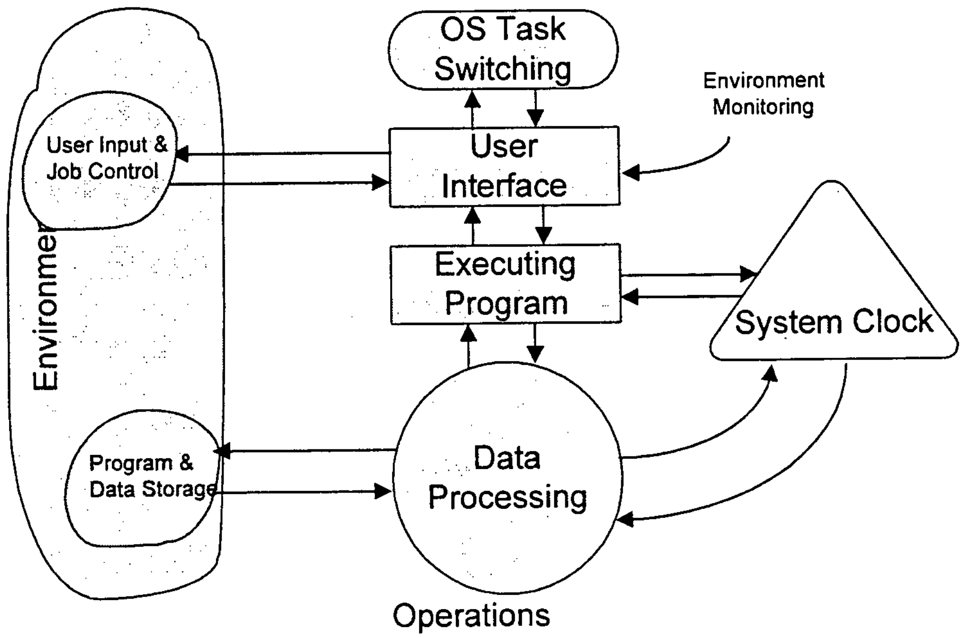


Figure 2-12 Model of a Computer System

Co-ordination is achieved by the system clock. Timing pulses issued by the clock ensure that every instruction is processed at the proper moment and drives the numerous control lines in the system.

With regard to information management Beer (1970) wrote "*...the problem of information management is now a problem of filtering and refining a massive overload. ..We might as well say that it is a problem not so much of data acquisition as of right storage; not so much of storage as of fast retrieval; not so much of retrieval as of proper selection; not so much of selection as of identifying wants; not so much of knowing wants as of recognising needs - and the needs are precisely the requirements of systematic equilibria. ...*

In any controlled system, there must be an hierarchic array of sub-systems, in which both the values and the structure of any one sub-system are set by a logically superior system. That is to say that one cannot discuss the purposive nature of a system in its own language, but only in a higher order language. There are potent reasons for this in theoretical logic, just as there are potent practical issues in terms of the need systematically to reduce the informational overload by a system of filters. These filters are necessarily arranged hierarchically, in a way which matches the hierarchy of the logical systems." This hierarchy of filters is illustrated in Figure 2-13 below.

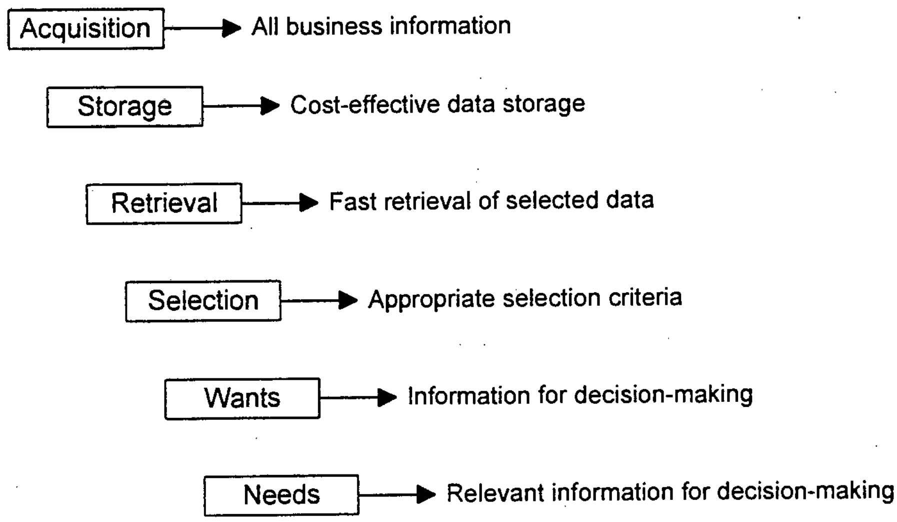


Figure 2-13 Hierarchy of Data Filters

It is clear then, that an effective information system must have the resources to acquire all information relevant to the business. Thus the information must be stored in a cost-effective manner so as to facilitate fast retrieval when it is needed. It must also be possible to formulate suitable search criteria to retrieve only the information actually needed - whether for decision-making, monitoring and control, or for operational purposes.

3. ORGANISATIONS AS SYSTEMS

Social systems, including organisations, fall into the class of extremely complex systems. The elements of a social system are people whose behaviour patterns are unpredictable and at times irrational, being shaped by genetics, upbringing, culture and environment. Klir (1969, p.viii) wrote "*The future of General Systems Theory and especially its practical applicability will depend considerably on our ability to solve problems that are intrinsically extremely complex and quite unmanageable*". Since then there has been an on-going effort to apply systems theory to this class of problem.

The earliest organisational model, pre-dating systems thinking, was the **bureaucratic** model developed in particular in the writings of Weber (see Gerth 1946) and Taylor (see Kreitner 1989 and Taylor 1911) and characterised by :

- Division of labour
- Hierarchy of authority
- A framework of rules
- Impersonality

The bureaucratic model ignored interaction with the environment. An organisation was seen as more or less successful depending on the degree to which it exhibited these characteristics. The organisation was viewed from a technical perspective leading to the conclusion that rigid structure and rational management were important in achieving organisational effectiveness. It was Weber's basic contention that "*man was unpredictable, often emotional, not necessarily rational, and would interfere with efficient organisational performance. He therefore set forth as an ideal model of bureaucracy a depersonalised form of organisation which would minimise the impact of human capriciousness*"(quoted by Johnson 1967, p.59).

This model fits production line industries using semi-skilled labour quite well because the semi-skilled worker is trained to perform a particular repetitive task which he carries out without too much thought. The bureaucratic model is also seen in many countries as an ideal on which to model the civil service. The concept of rules applied impersonally to all alike, no matter what their station in society, is seen to correspond to the desire for an honest and democratically accountable administration. The bureaucratic system represented by this model is relevant to this study because GIS is in large measure a function of the administration, or public sector, at one level or another.

Viewed from a systems perspective, many eminent writers have regarded the bureaucratic model as a **closed system**, corresponding to Type 3 (control systems) of Boulding's hierarchy above. Nevertheless it is obvious that social systems (not even bureaucracies) do not actually operate as closed systems. The civil service has to interact with a continually changing environment, facing political and legislative changes, reorganisation and changes in technology. For this reason this type of system is sometimes classed as a **relatively closed system,** in contrast to modern commercial enterprises which can reasonably be described as **open systems**.

In the early 1960's, the ideas (General System Theory) put forward by von Bertalanffy were taken up by the business community. In "The Theory and Management of Systems" Johnson (1967) showed a business to be an open system. He drew an analogy with a human body with the various organs representing the operating divisions of the firm, the skeletal and muscular system representing the physical organisation, the circulatory and nervous systems representing control and information flow between the various sub-systems, and finally, the brain representing the management who direct the operation of all the subordinate components.

Ludwig von Bertalanffy's 'open system' maintains its structure in a changing environment - i.e. it maintains dynamic equilibrium, or homeostasis. This is done through interaction with the environment in the case of the animal, exchanging food, heat, waste products etc. In the business system the dynamic element responsible for maintaining equilibrium was identified as the flow of resources.

The resources used within a business include raw materials, partially finished and finished products, capital, cash, labour and data. The latter includes orders and invoices, requisitions and receipts, and reports on cash-flow, asset value, stock inventory etc. No matter what type of business, the bulk of the resource flow comprises **information**.

If the dynamic of a business is the flow of resources, then it follows that an effective management technique must be able to cut across many organisational disciplines such as finance, manufacturing, design, marketing, sales etc. while still carrying out the function of management (Kerzner 1992). This conclusion has given rise to the technique called systems management or project management.

3.1 Organisations

In the modern world almost all productive work is carried out by organisations, be they state bureaucracies, large multi-national companies, small private firms or partnerships. Outside the area of art or professional practice, the one-man business is very rare. Because of this, and because one of the main functions of the corporate information system is to improve communications within organisations, it is necessary to consider the organisation from a systems perspective.

Since the 1960's it has been recognised that the *open system* described by General Systems Theory provides a useful model for studying organisations. Stacey (1993) puts it as follows:
"The open system concept provides a tool for understanding the relationship between :

- *the technical and social aspects of an organisation;*
- *the parts and the whole organisation (for example, the individual and the group; the individual and the organisation);*
- *the whole organisation and the environment."*

Numerous views have been put forward to explain how the organisation functions as an open system. These views fall into two main categories, those stressing the control function based on negative feedback to promote organisational stability, and those which stress the flexible nature of organisations in a changing environment.

Earlier writers such as Stafford Beer (1981) and Ashby (1957) worked on cybernetic principles which focused on the control aspects of organisations. This was natural at a time when changes in the environment in which organisations operated were slow. However, in the 1990's environmental changes are extremely rapid, and the very stable organisations which have survived from the past are finding it difficult to react quickly enough to the changes going on around them. Many large companies such as IBM and Olivetti bear witness to this.

More recent writers such as Stacey (1993) and Morris (1993) focus much more on change, and in particular on positive or amplifying feedback loops which lead to chaotic change. Nevertheless, while the focus has changed, the arguments still rest on cybernetic theory.

Hoebeke (1994) has extended the work of Beer and Checkland in a very convincing way. His key points are :

1. that organisations, committees, departments etc. do not provide services to customers - people do. "*In practical work each of us is dealing with networks of living people, who are more or less distant from our concerns and the purpose we attribute to our activities. With these people we have our strategic debates. They are our allies, enemies, friends, adversaries, or a combination of them in different settings. They form the real network of relations in which we deploy our activities. They are partners in our work systems. Anonymous relationships are a contradiction in terms.*"(1994 p.37) Every businessman knows the importance of personal relationships to business success.
2. that businesses processes form a hierarchy related to time span, with higher levels related to longer time spans. Each higher level of process does not <u>manage</u> the activities of a lower level, but <u>creates the conditions</u> in which the lower process can be performed.
3. that business process levels or strata can be grouped in four domains:

   The value-added domain (1 day - 2 years)

   This is where outputs of direct value to customers are produced using existing resources and technology.

   The innovation domain (1 - 10 years)

   This is where market strategies, new technology , and new products are developed.

   The value-systems domain (5 - 50 years)

   The value-system domain is where political debate takes place leading to cultural changes. Political debate is an on-going feature of human society. Vickers (1983) writes "*Political activities refer to* *interactions between proponents of different value systems not to achieve a certain form of consensus or compromise but to agree that it is worth continuing the debate and its underlying relations."* Hoebeke (1994 p.104) also points out that *"activities in the value-systems domain are always inter-organisational"*.

The spiritual domain (20 - 50 years)

The spiritual domain is concerned with the ultimate meaning of life and death, and existence. Many artistic and religious work systems function in this domain.

Hoebeke's **value-added** and **innovation** domains are relevant to the developments of computer information systems because the introduction of information technology represents an innovation to a firm which must be properly planned. Thereafter the technology or innovation must be transferred to the **value-added** domain.

3.1.1 Rationality

Rationality is an important concept when studying the behaviour of organisations. When predicting how an organisation will react to particular circumstances such as the introduction of a GIS, it is necessary to assume that the decision makers in the organisation will act in a rational way. This leads to an immediate problem since rationality has several meanings which are not distinguished in everyday speech.

Stacy (1993) defined three common meanings of rationality as follows:

1 Behaving and deciding in a manner connected to reality, and judged likely to bring about desired consequences. **Irrationality** implies being fantasy-driven, while rationality involves testing for reality where that reality may well be of an emotional, ideological or cultural kind.

2 Behaving and deciding only on the basis of propositions which can be consciously reasoned about, rather than on the basis of customs, norms, emotions and beliefs. **Irrationality** here consists not only of fantasy, but also of behaviour driven by emotions and beliefs even if they are connected to an emotional and ideological reality.

3 A method of deciding which involves setting clear objectives, gathering the facts, generating options and choosing one which optimises or satisfies the objective. **Irrationality** is any behaviour whatsoever that is not preceded by fixing objectives and weighing up options based on observable facts.

Definition (1) is synonymous with 'sane' or 'reasonable'. In this sense it is perfectly rational to take account of intuition and feelings when making a decision. Definition (2) corresponds to formal logic. A rational decision can only be made on the basis of logical propositions which follow from solid facts. Stacey calls definition (3) **technical rationality**. Technical rationality may on occasions be quite irrational (in sense (1)) if, for example, it fails to take account of external political or economic factors. Stacey adopts the second definition and shows that, from this perspective, decision making is done in both rational and irrational modes.

In the context of system development it is rational to adopt definition (1). Behaviour which leads to the desired outcome, whether it mixes superstitious belief with logic or not, must be considered rational. For example, it may be technically irrational to use a geomancer to arrange the layout of a computer room based on *fengshui*, nevertheless it will be rational to do this if the result is that the computer system is successful, where success is brought about by the users' belief that the layout is correct.

3.1.2 Communication

An overview of communications was given in Section 2.2 above. Communication is the life blood of the organisation. Because effective communication is one of the prerequisites of a viable organisation, it is important to be aware of all the different ways in which communication occurs (the media), what facilities there are for the transmission of communication (the channels), what factors impede communication (noise) and what makes for more effective communication (interpersonal skills and cultural studies).

3.1.2.1 Communication in Organisations

An organisation cannot exist without communication between the various departments. In mechanical or electronic systems, this communication takes place through mechanical or electronic linkages. The self-steering gear of a yacht for example, has a mechanical linkage to the tiller which corrects the course should the wind change direction. In biological systems communication takes place through chemical agents such as hormones.

Communication in an organisation is information flow - commands and instructions to get things done, feedback for monitoring how they are done, and intelligence to support decision making.

3.1.2.2 The Communication Model

While relevant to the transmission of electronic signals, Shannon's Theory of Communication is not a sufficient basis from which to understand communication in social units - for example, communication through 'body language' cannot, at present, be quantified or reduced to mathematical terms. Hence the linear communication model described in Section 2.2 is not appropriate in dealing with face to face communication. In this case an interactive model as illustrated in Figure 3-1 is more suitable. In the interactive model the receiver gives continuous feedback through facial expression, body language, and comments like 'Aha!', 'I see' etc. This feedback enables to the sender to modify the manner in which his message is transmitted, to ensure it is received correctly.

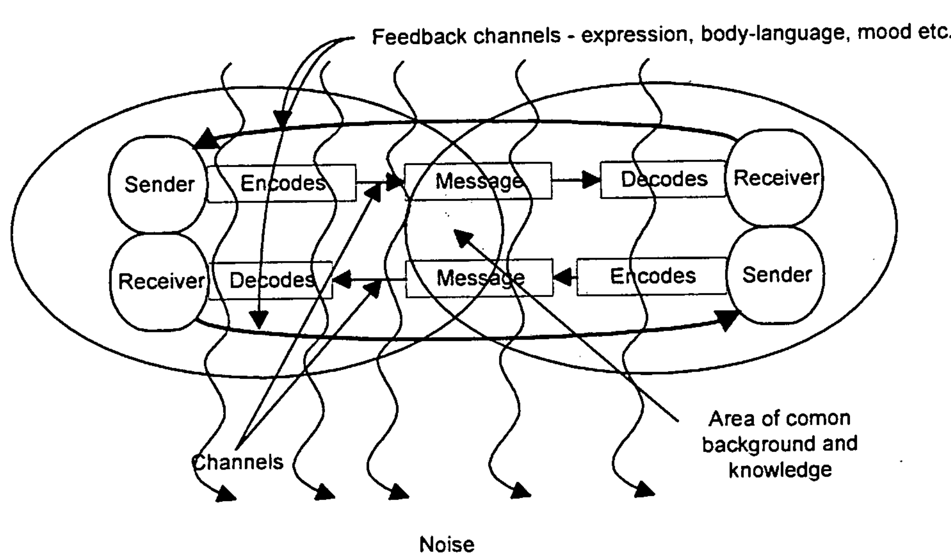


Figure 3-1 An Interactive Communication Model [Adler 1990, p.13]

3.1.2.3 The Medium of Communication

Within an organisation communication is transmitted in writing on paper and electronically, orally face to face and by telephone, formally and informally, and so on. Ideas must be expressed in language before they can be communicated to others by spoken or written word.

When the spoken word is written down ('encoded') to send the message through the postal and the other communication channels mentioned, the intonation, expressions, and gestures used in face to face communication are all lost and with them a significant part of the meaning. In other words, the linear rather than the interactive communication model holds.

3.1.2.4 The Communication Process

In the office context, the information source may be an idea in the mind of a manager. In order to transmit his idea to a colleague, he must first encode it by expressing it in language, and then speak the words. His colleague receives the signal by hearing the words and understanding them. There are a number of places where this communication can go wrong. The speaker may have a problem in expressing his thoughts in language, as many people have difficulty in saying exactly what they mean; the receiver may not understand the language into which the message is encoded; he may understand the words but not their intended meaning. In this regard Beer (1979) writes "*The translator is (I just admitted it) a perfect linguist. But does the translator personally comprehend - not my words - but the number of possible states that I intend to evoke by my words. No: neither he nor she, in my experience, deploys that much variety.*"

3.1.2.5 Noise in Communication

Technically the factors impeding successful communication are referred to as 'noise'. Noise includes **external noise**, **physiological noise** and **psychological noise**.

- External noise refers to all the factors which may distract a listener such as actual noise, distracting sights and sounds etc.

- Physiological noise refers to problems with the receiver and sender e.g. hearing loss, speech impediment, illness and so forth.
- Psychological noise is the most difficult to deal with because the sources are complex. It includes the receiver's mindset, cultural background, religious beliefs, mood etc. as well as the skill of the speaker in presenting his message [Adler 1990].

In the context of an organisation, the relative position of the speakers in the organisational hierarchy is an important source of psychological noise, for example, a simple suggestion by a superior may be interpreted by a subordinate as a command.

Noise is also produced by preconceptions, for example the people communicating may have had previous unpleasant meetings or may have heard rumours about the person they are meeting. These preconceptions will colour their understanding of what is being said at least until they become well-acquainted with the other party, and possibly form new perceptions.

Another factor is 'personal chemistry'. Some people instinctively like or dislike someone on first meeting and this colours all their subsequent communication. Factors which may affect personal chemistry include 'manners' i.e. behaving in a manner regarded as appropriate by the particular culture. This might include personal grooming, smoking, dress, mode of speech, and even the point in a meeting at which it is appropriate to introduce the real purpose of the meeting.

If communication is made at an inappropriate time, for example when an officer is given instructions when he is on the point of leaving the office to go home; or in an inappropriate place, for example if a reprimand is given in public the message will not be well received.

Poor presentation is also a form of psychological 'noise' which interferes with the reception of the message. The information received from charts and graphs is strongly influenced by the axes and scale adopted. It is well known that the same data can be used to support differing view points, simply by changing the way in which the data is presented. It is common experience that a well-drawn map with a high cartographic standard inspires the confidence of the user, no matter what the actual accuracy of the data recorded on the map.

Non-native speakers of a language rarely understand all the nuances and idioms of the language. They may also confuse native speakers by translating idioms and expressions from their mother tongue. With ever-increasing international trade and commerce, people are forced to use foreign languages in their day to day business - in most cases English. Thus Indonesians and Japanese will normally conduct business meetings in English though neither group may be particularly competent in English. Under these circumstances the scope for misunderstanding is enormous.

Misunderstandings also occur between native speakers from different dialect groups - the differences between British and American English are well known.

Many people have difficulty in expressing their intentions in speech or writing. This is often blamed on the education system, but whatever the cause, it results in misunderstanding in the workplace.

Until fairly recently it was thought that in face-to-face meetings, when people show their feelings through their tone of voice, expressions and body language, the listeners could always tell whether the speaker was friendly or hostile, sympathetic or unfeeling. Similarly, it was thought that the speaker could tell whether the listener was interested or bored. This is true when the people involved in the communication belong to the same culture, but recent research by Tang Siu Wa, reported in the *Straits Times* of February 2nd 1998, shows that American facial expressions are often misunderstood by Japanese and vice versa. Hence it cannot be assumed that facial expressions are understood between different cultures. This factor may contribute to mis-communication.

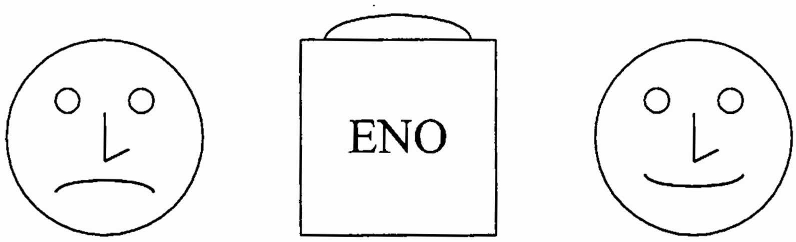
A further source of noise may stem from corrupt practices. A man hoping to be offered a bribe seldom asks plainly for what he wants, even in the most corrupt countries. It is left to the other party to work out why the contract is being delayed. Business partners from 'straighter' environments may not understand what is required at all. Middle men are often used to clarify such communications.

In written communication these cues are missing, and can only be partially conveyed by the tone of the writing. Non-native speakers may write in a brusque unfriendly tone quite unintentionally simply through not knowing the nuances of the language.

3.1.2.6 Spatial Information

Spatial data makes up a major part of the contents of geographic information systems. Language is not well adapted to conveying spatial data. A simple sketch map may convey information which would require a lengthy verbal description. Maps and pictures are a much more efficient means of communicating spatial data.

Pictures can convey a great deal of information which would be very difficult to send any other way, hence the saying "a picture is worth a thousand words". A word of caution here though - spatial organisation differs in some cultures e.g. Arabs read from right to left and may therefore try to follow a sequence of pictures in the reverse order from that intended. The advertisement on which the drawing below is based, is reported to have been widely misunderstood by Arabs.



One glance at a map is enough to learn the spatial layout and relative positions of the main topographic features in a district. The same information would be extremely difficult to convey in words.

3.1.3 Communication Channels

Within an organisation communication takes place through various media and along various channels. They can be classified as shown in the table below:

Medium	Channel	Formal	Informal
Writing	Letter	Letter of Appointment or Dismissal	Memo to colleague
	Fax	Letter to a Customer or Supplier	Information to a colleague
	e-mail	*always informal*	Operational information
Speech	Face-to-face	Interview	Informal meeting
	Telephone	*seldom*	Most operational communication
Non-verbal	Expression, posture (body language)		
	Signs		

Table 3-1 Classification of Communication

Kydd (1989) uses the concept of **richness** of communication to encompass messages given by non-verbal means such facial expression, tone of voice, and body language. She writes "*Richness of information refers to how well a particular communication transaction is able to overcome differing points of view or clarify ambiguous issues in a timely manner*". In contrast to richness of information is **amount** of information which "*refers to the quantity of data which will be sufficient to answer the questions that arise from the situation at hand*".

Most organisations have formal communication channels which are linked to the organisational structure. In traditional organisations, general formal communications move in a hierarchical fashion between heads of units. This is clarified in Figure 3-2 below. It is clear that this presents a very inflexible and inefficient communication network. For example, Department Manager 1A cannot talk directly to Department Manager 1B; his communication should go via his Divisional Manager (A), who will in turn communicate with Divisional Manager (B). He, in turn, passes the message to Department Manager 1B.

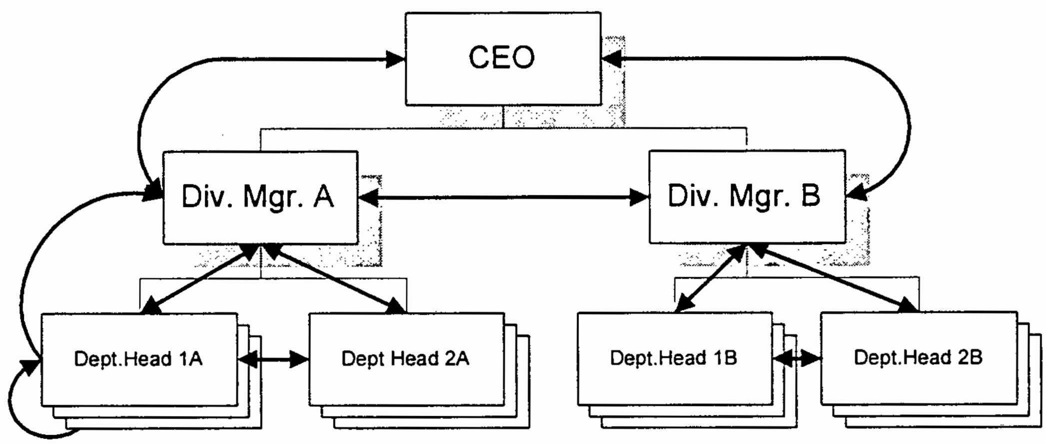


Figure 3-2 - Formal Lines of Communication

Several issues are at stake here. If subordinates communicate directly with their manager's superior, the manager may feel that his staff are not showing him proper respect. If a subordinate communicates directly with his counterparts in other divisions, his manager may fear losing control of his department, and may in fact lose control. The manager also has a monitoring and controlling function, so he must satisfy himself that all correspondence and reports leaving the office are of good quality.

It is obvious that this type of communication is not always the most efficient. Each manager represents a bottleneck in the flow, because a number of employees are generating communications which must all flow through him.

Matters are worse when different languages are combined with a hierarchic communication structure, for example in at least one Middle Eastern country, technical correspondence between civil service departments is prepared in English by technical staff, sent to the manager who has it translated into Arabic before sending it to his counterpart in the other department. The document is then translated back into English, and sent to the corresponding technical officer for his attention. The delays and possibilities for misunderstandings arising from double translation can be imagined. This problem is often solved by a parallel informal exchange of English correspondence between the technical officers.

Communication channels are more than a technical matter. According to Eilon (1979, p.114) "*observations of the behaviour of managers leads one to conclude that some believe that they retain power by withholding information from others. ... This is one reason for the resistance that is often encountered from managers to the installation of a computer to take over the processing of information relating to their work; they may then lose control over who the information is made available to, and this restricts their own room for manoeuvre and affects their role as decision makers.*"

Until quite recently the transmission of written communications was confined to the postal service and messengers. The introduction of fax machines has made possible the instantaneous transmission of documents and has revolutionised business. The new channels of communication offered by computer networks promise an even greater revolution.

The telephone has been in widespread use for about seventy years, but fast and reliable international telephone links have only been available for the past twenty years. This too has had a major impact on business, making it much easier to deal with customers, suppliers and branches situated overseas.

Video telephones and video-conferencing are slowly becoming available, but the technology is not yet mature. In the near future one can expect that video-telephones will become widely used as the price falls, and the problem of limited band-width on existing telephone lines is solved. This will overcome the "weakness" of not being able to see the person one is speaking to on the telephone.

Telephones link every desk, but the same hierarchical constraints found with written documents exist with the telephone. Managers' secretaries often filter calls to exclude those which are contrary to the established protocol, or to gain benefits from those who are allowed to speak to the manager.

The computer network transforms the communication channels within the organisation. Electronic mail can be sent from any desk to any other desk, regardless of positions in the hierarchy.

3.1.4 Monitoring and Control in Organisations

Newman and Summer (1961) put it thus:

1. *Standards that represent desired performance. These standards may be tangible or intangible, vague or specific, but until everyone concerned understands what results are desired, control will create confusion.* [i.e. the goals must be defined and made known to everyone].
2. *A comparison of actual results against the standards. This evaluation must be reported to the people who can do something about it.* [i.e. monitoring].
3. Corrective action. Control measurements and reports serve little purpose unless corrective action is taken when it is discovered that current activities are not leading to desired results.

Johnson (1967, p.72) defines control as "*that function of the system which provides direction in conformance to the plan, or in other words, the maintenance of variations from system objectives within allowable limits*". This definition brings out the point that it is impossible to keep a system exactly on course and that limits of allowable variation must be defined.

In the viable system model the monitoring and control function is performed by the VSM *System 3* (see pp.2-18).

3.2 Classification of Organisations

Systems may be grouped and classified in many ways. Flood (1991) suggests a classification which is useful when viewing organisations as systems. It is based on a continuum specified by the matrix below:

	Relationships		
	Unitary	**Pluralist**	**Coercive**
Simple	Simple-Unitary	Simple-Pluralist	Simple-Coercive
Complex	Complex-Unitary	Complex-Pluralist	Complex-Coercive

At the "simple" end of the spectrum, the system is characterised by:

- a small number of elements
- few interactions between elements
- elements with pre-determined attributes
- highly organised interactions
- well-defined laws governing behaviour
- a system which does not evolve
- sub-systems which do not pursue their own goals
- a system largely closed to the environment

"Complex" systems are characterised by:

- a large number of elements
- many interactions between the elements
- elements the attributes of which are not pre-determined
- loosely organised interaction between elements
- elements which are probabilistic in behaviour
- a system which evolves over time
- sub-systems which are purposeful and generate their own goals
- a system which is open to the environment

In "unitary" systems the elements all

- share values and beliefs
- agree upon ends and means

- participate in decision making
- act in accordance with agreed objectives

In a "pluralist" system the elements

- have diverging values and beliefs
- do not necessarily agree on ways and means but are prepared to compromise
- all participate in decision making
- act in accordance with agreed objectives

In "coercive" systems

- elements have values and beliefs which are likely to conflict
- elements do not agree on ways and means and compromise is not possible
- some elements coerce others to accept their decisions

Figure 3-3 illustrates the area within this matrix where the organisations most likely to be developing GIS are located.

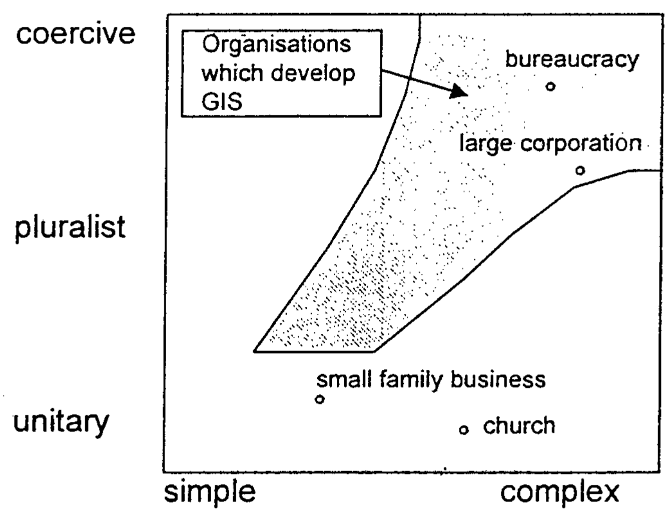


Figure 3-3 An Organisational Classification

It is in the nature of geographic information systems that they often attempt to span a number of semi-independent organisations. Data is produced and maintained by several organisations, and used by several others, as is illustrated in Figure 3 - 4 overleaf. The GIS is in fact functioning in a super-system which comprises several organisations. This super-system is a complex-pluralist system. One way in which it might be made to work is by moving it to the coercive-complex model by ensuring that the higher authority e.g. prime minister, forces all the organisations involve to co-operate as shown in Figure 3-5.

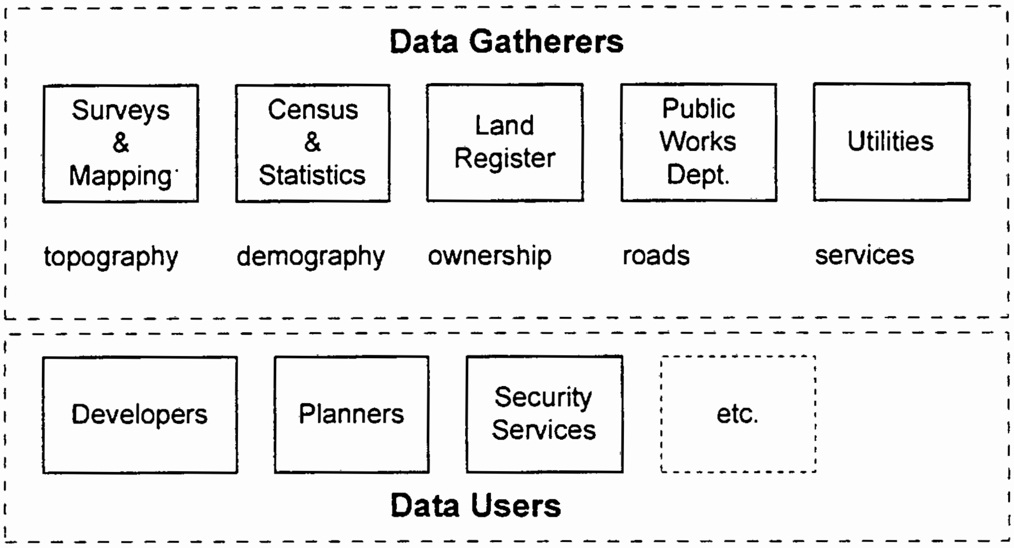


Figure 3-4 A Geographic Information System May Span Several Agencies

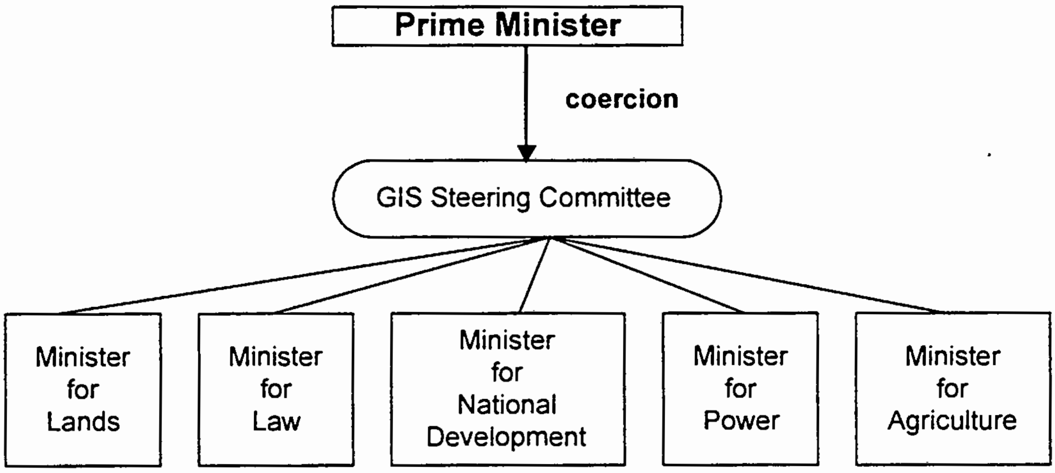


Figure 3-5 Using Coercion to Achieve Co-ordination

The fact that an infinite variety of organisational types can and do exist has resulted in numerous ways of applying systems thinking to organisational analysis. These can be divided very roughly into the cybernetic and the "soft" systems approaches.

The cybernetic perspective has grown from the study of control systems and appears to be more strongly based in logic, and hence has a stronger appeal for engineers and accountants. This approach is represented by the **viable system model** (VSM) developed primarily by Stafford Beer (interestingly enough, not an engineer but a philosopher and psychologist).

The "soft" systems methodology is built on the work of Churchman and Akoff. The key to this thinking is given in three statements by Churchman (1968):

- *The systems approach begins when first you see the world through the eyes of another.*
- *The systems approach goes on to discover that every world view is terribly restricted.*
- *There are no experts in the systems approach.*

These statements, while open to argument, provide an insight to the value of the systems approach. The first statement highlights the fact that we each bring to a problem our own pre-conceived ideas, consistent with our education, culture and experience. We are thereby inevitably viewing the problem in a subjective way. That is to say, an analyst with a different culture and upbringing might see the same problem in a completely different, but equally valid way.

The second statement leads on to the idea that an objective analysis of the problem requires the synthesis of analyses from contrasting view points. No individual has the 'right' solution.

The third statement points out that in matters of aims and objectives involving moral judgements, there are no experts and a wide variety of opinions should be sought.

The "soft" systems approach is considered particularly suitable for dealing with difficult and intractable problems. It is also a valuable approach when the organisation and the analyst do not share the same cultural background.

3.3 Organisational Culture

The importance of culture in system development has been stressed above in connection with communication. Figure 3-6 overleaf presents a conceptual framework for analysing organisational culture adopted from Davies (1989 fig.2.3). This framework shows how the values and technology of the ambient society, combined with the organisation's history, and its founder's vision, drive the development of an internal organisational culture. This legitimises the organisational policies and structures, and provides role patterns for the individual members of the organisation.

Difficulties arise when the ambient culture does not support the economic and technological environment, and when rapid staff turnover does not permit new members to be adequately socialised into the organisational culture.

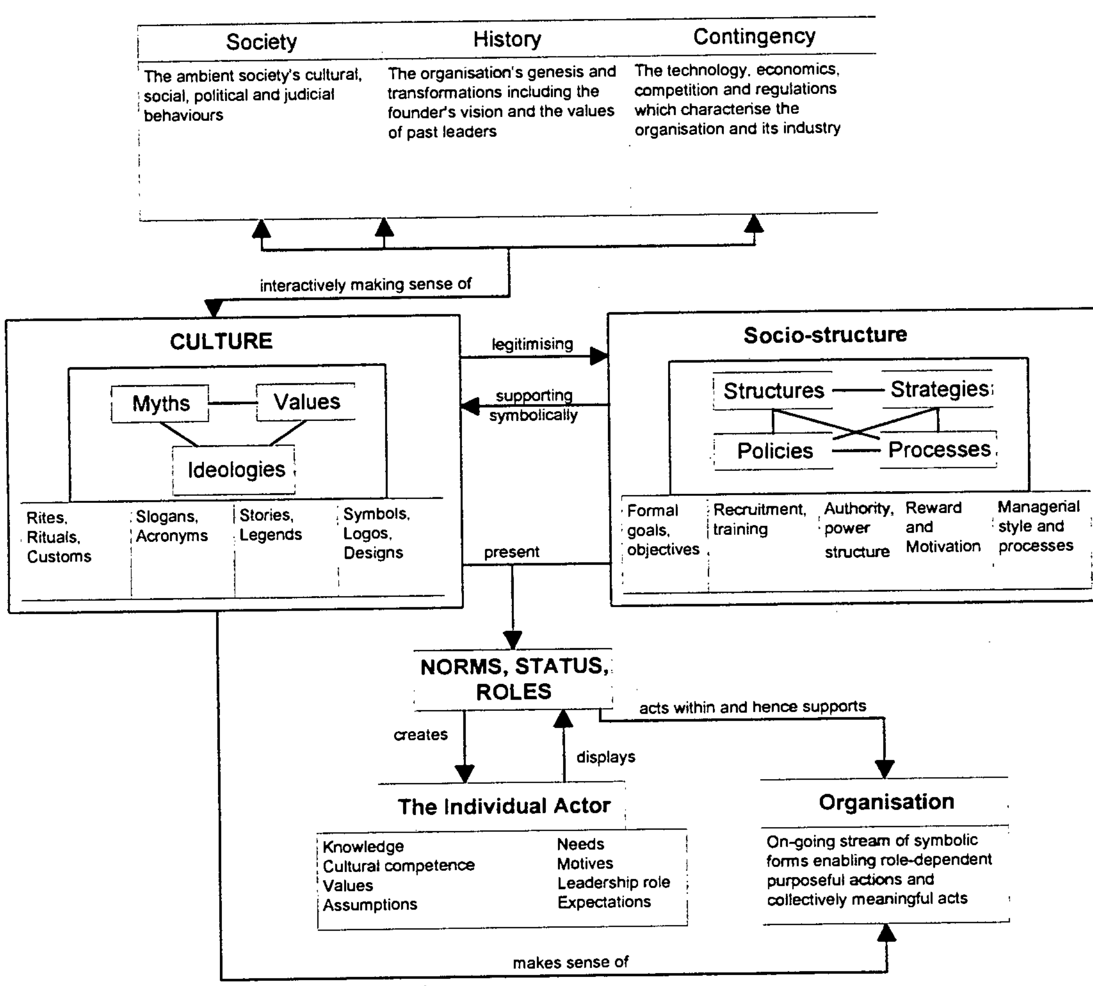


Figure 3-6 A Conceptual Framework for the Interpretative Analysis of Organisational Culture (Davies 1989 Fig. 2.3 p.42)

4. CORPORATE INFORMATION SYSTEMS

Organisations have always maintained information systems, though in the past they may have comprised information held in the memories of the tribal elders, or written records stored in vast archives. The introduction of a computer-based information system means change for the organisation. The organisation must adapt to readily accessible central data stores, high speed communications, and new possibilities in data analysis, while the computer system must be customised or programmed to meet the needs of the organisation. This is a two way adaptation - the organisation must adapt to the constraints imposed by the computer system, and at the same time the computer system must be adapted to the organisation through modification and customisation to meet users' requirements. Wessel (1979, p.2) wrote "*Adaptation is not a one-way street. It applies to both the systemsware and user organisation (machines and people)*".

All changes begin from the present situation, therefore some information on the development and classification of computer systems is relevant. It throws light on the present situation in the field of information systems and explains how this position has been reached.

4.1 Computer-based Information Systems (CBIS)

If one accepts the open system model of the business organisation, then it follows that data is an important part of the *resource flow*, and it is this resource flow which makes up the dynamic of the organisation. Quoting Wessel (1979, p.2) again "*Information, its flow and control lie at the heart of things*". Using the anatomical analogy, data flow within an organisation corresponds to the information passed to the brain by the various sense organs, and to the controlling messages sent to the muscles and other organs.

In order to understand how the hybrid man/machine system is created, it is necessary to keep the historical perspective in mind so as to understand how computer systems have developed in the past half century. This view forms the mind-set or thought paradigm of the majority of people involved in the management of electronic data processing, and it is this paradigm which must be broken before the holistic approach to the all-inclusive corporate information system can be adopted.

Computer-Based Information Systems (CBIS) perform several different functions in modern businesses. All too often these functions are studied from the reductionist perspective. Table 4-1(Kroeber 1990, p.5) shows a widely accepted functional classification. Although the various functional modules are logically sub-systems of a single integrated CBIS, it is only recently that this fact has been recognised, and it is certainly not made clear in Kroeber's classification. It is important that unity should be kept in sight when designing systems, so that the mistakes of the past are not repeated by creating more data processing 'islands'. These most often result from failure to perceive the unity of the system. In mitigation it should be remembered that development has proceeded sequentially. Each class of system was only implemented when the enabling technology became available. The 'whole' at any time is bounded by the available technology.

Type	Inputs	Processes	Output
TPS Transaction Processing System	Transaction data	Classifying, sorting, adding, deleting, updating	Detailed reports, processed transaction data
MIS Management Information System	Processed transaction data, some management-originated data, pre-programmed models	Report generation, data management, simple modelling, statistical methods, query response	Summary and exception reports, routine decisions, replies to management queries
OAS Office Administration System	Appointments, documents, address lists	Scheduling, word processing, data storage and retrieval	Schedules, memoranda, bulk mail, administrative reports
DSS Decision Support System	Some processed transaction data, mostly management-originated data, unique models	Query response, management science/ operations research (MS/OR) modelling, simulation	Special reports, input to difficult decisions, replies to management queries
EIS Executive Information System	Processed transaction data, reports and data analyses	Information retrieval, personalised analysis	Current status, projected trends, revised information
ES Expert System	Facts and production rules	Inferential responses to queries	Solutions to problems which usually require the skill of experts

Table 4-1 Classification of Computer-Based Information Systems

There are still strong forces holding back the development of integrated corporate information systems, but these are organisational and political rather than technical. They include fear of losing power, fear of more effective management control through better performance monitoring and shortages of skilled manpower.

On the face of it, Kroeber's classification is functional, but it is in fact biased towards technology. This method of classification would regard GIS as yet another distinct type of system, a view militating against the corporate information system. A better classification is shown in Figure 4-1 below. In this case the system function is clearly related to the business function without regard to the particular technology (such as AI, GIS, OLTP etc.). This classification is more in tune with the systems approach to the organisation.

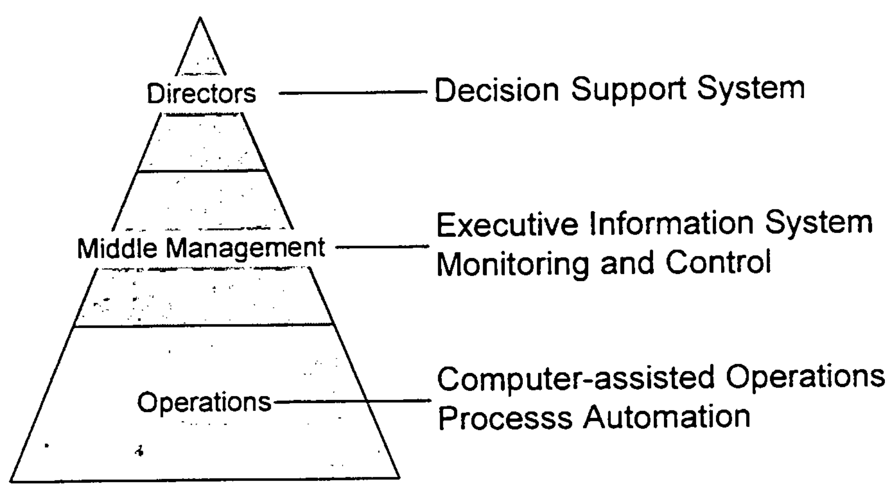


Figure 4-1 A Functional Classification of Computer-based Information Systems

4.1.1 Development of Computer Systems

Computers have been gradually introduced into businesses over the past forty years. At first they were very large, very expensive and limited in their capabilities compared with what is possible today. They were used chiefly by banks, insurance companies and government departments. Over the years, the power and performance of computers has increased while their cost has fallen steadily. The continuous increase in the performance/price ratio, and in the demands of users have been the chief factors in driving the development of computer-based information systems.

A brief outline of this development is a useful prelude to a consideration of future directions. As will be shown, the future trend is towards an all-embracing CBIS not only encompassing applications such as GIS, CAD, Project Management, accounting, and database management, but also managing documents and driving business processes through automatic control of the flow of work.

The development of CBIS may be viewed from different perspectives - as either evolutionary, hierarchical, or requirements driven (see Kroeber 1990, pp.9-13). Some writers class development as either technology-driven or requirements-driven, but there is good reason to believe that technology and user requirements operate in a feed-back loop, see Figure 4-2 below i.e. the initial technology is developed to meet a specific user requirement. This technology then widens the perspective of the user who is able to formulate previously undreamed of new requirements.

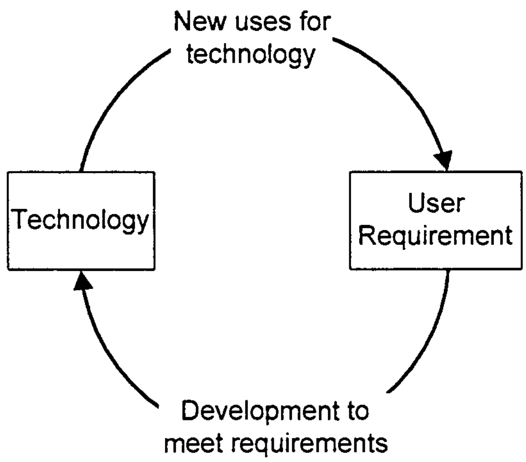


Figure 4-2 Technology and User Requirements in a Feed-back Loop

The first commercial computer installations were used for financial accounting, especially in banks and insurance companies where large numbers of customer accounts have to be processed. Tasks include the generation of statements and renewal notices, computation and crediting of interest, posting of debits and credits arising from deposits, cheques and bank charges. This type of processing involves relatively simple computations performed repetitively on a large number of accounts. Such computations are performed in 'batch mode' i.e. once the program has been started, it continues without operator intervention until all the records have been processed. Systems of this type are called 'Transaction Processing Systems'. Nowadays they operate 'on-line' as well as in 'batch' mode. Typical batch processes include generating telephone or electricity accounts once a month, and updating customers' accounts with interest earned in the preceding period. Examples of 'on-line' transaction processing systems include airline reservation systems and bank ATM networks.

It was a short step from processing transactions to generating reports on the transactions. These reports are of value to management in formulating policies and making business decisions. Hence transaction processing systems were extended to print reports on, for example, the number of accounts processed, the maximum, minimum and average balances etc. This extension to the system is known as a 'Management Information System' (MIS).

An offshoot of the MIS is the Executive Information System (EIS). This is an MIS provided with a very easy to use graphical user interface (GUI) which can be used by senior executives who are only occasional users of the system.

The next step in the evolutionary process was to enhance the functionality of the MIS. This was done by providing software modules for producing special-purpose 'one-off' reports and for modelling various possible business scenarios - in other words, answering the question 'what if?' The enhanced MIS was now termed a 'Decision Support System' (DSS) because its primary function was seen to be supporting management decisions by providing information and predicting the most probable results of the various choices available.

Decision Support Systems were taken a step further by the Expert, or Rule-based System. The Decision Support System merely provides information and models different scenarios. The Expert System combines the information with a set of rules (or knowledge-base) which are followed in the decision making process. The rules are specified by experts who provide the criteria for decision making. Expert Systems are still in an early stage of development, but it is clear that they that they will have a major impact on all computer systems in the long run. Experimental expert systems have been built on geographic information systems, for example the Italian National Park Management System. In

Singapore, research is being done on the automatic checking of building plans for compliance with building regulations.

The systems described above have their roots in the large mainframe computers which were installed in big companies in the fifties and sixties. **Office Administration Systems**, on the other hand, have their origin in the mini- and micro-computer field. In the late seventies, the first micro-computers appeared on the market. Initially they were not taken seriously by data processing professionals, but the enthusiasts who used them found that they were ideal for some tasks such as word processing and financial modelling on spreadsheets. The use of micro-computers spread rapidly. Soon they were being linked to form networks. This opened up the possibility of communication between members of work groups by electronic mail. Connections to mainframe computers followed and from that point client/server computing has developed. This development is continuing towards **distributed computing** in which the server is replaced by multiple servers and the databases are distributed amongst these servers.

4.1.2 Engineering Computing

In addition to the systems outlined above, a large number of organisations also use computers for scientific and engineering work. The tasks performed by these computers are distinguished from business tasks by intensive computation, and the use of advanced graphics.

Computers used for engineering work have different requirements from those used for general business tasks such as accounting and stock control. The main differences are highlighted in Table 4-2 overleaf.

In the past, the different functionality needed, and the lack of system integration tools, justified the development of engineering systems in isolation. Thus in many organisations one can find design departments using CAD software, survey departments using computer-assisted land surveying software or GIS, building departments using independent quantity surveying and project management software. It is clear that, from a functional perspective, integration of these data processing islands is essential.

Computer Feature	Business Computing Requirements	Engineering Computing Requirements
CPU	Integer arithmetic	High speed floating point arithmetic
Input/ Output	Must support large number of terminals or clients (multi-tasking or client/server)	Usually 'stand-alone' or net-work connection
Secondary storage	Very large capacity disk and tape drives	Medium size ~~internal~~ hard disks
Important peripherals	High-speed heavy duty line printers	High-resolution graphic display terminals, plotters, digitisers

Table 4-2 Hardware Requirements for Commercial and Engineering Computing

A design is only a step on the way to a finished product. The surveyor's site plan is the basis for the architect's design which in turn is used for structural steel or reinforced concrete design. The architect's plans and the structural design together are used by the quantity surveyor to produce his bill of quantities. The bill of quantities is used for costing and for generating orders for materials. The delivery time-table for the materials acts as a constraint in the project scheduling, and finally, the architect's specifications and the quantity surveyor's costing provide a yardstick against which progress is monitored and payments are made. This chain of sub-processes is illustrated in Figure 4-3 below.

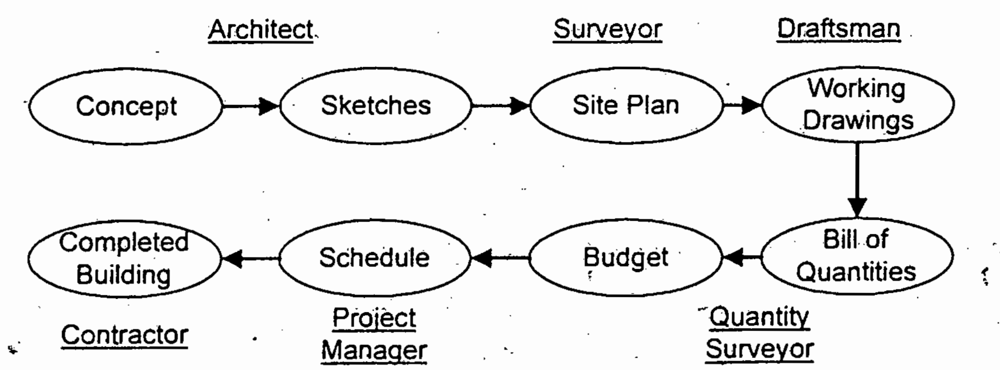


Figure 4-3 Each Stage in Construction takes Inputs from the Previous Stage

Thus each sub-process along the way receives data from a preceding process, and also passes on data to subsequent processes. At present this is done almost entirely in the form of papers, drawings and printed schedules. There are two reasons for this. First, each department has its own software which in general, stores its data in a different format from that of other departments. The second reason is that there are many difficulties in connecting hardware using different operating systems and network protocols. This is not to say that a giant software package should be developed that can do everything, only that each software package should be able to read and write data in a format that the next system in the processing chain can read.

This problem can and should be solved, particularly if the user is planning the introduction of additional computer-based systems. Office automation software is giving a lead in this direction. Programs such as Microsoft Word, Excel, Project, Vision etc. can all share data, in most cases quite transparently to the user.

4.1.3 Geographic Information Systems

This thesis is about the development of large-scale geographic information systems (GIS). Therefore it is worthwhile looking at the main features of such systems, the problems involved in integrating them into corporate information systems, and the special problems encountered in dealing with spatial data.

On the whole, geographic information systems have developed independently from other computer systems. Since the sixties computers have been used as an aid to surveying and mapping. Maps were captured and stored digitally and plotted with digital plotters. In the early stages of development, the computer simply stored sets of points and lines which, when they were plotted, reproduced the paper map. During this period no attributes were attached to the graphic elements other than those needed for plotting, for example, colour, line type, hatching pattern, symbol etc. It was not until the seventies that it was realised that extensive attribute data held in textual databases could be linked to graphic elements. This linkage began the transformation of digital mapping systems into geographic information systems, a process which continues today.

Because the development of GIS began in the surveying and mapping community[Mark 1997], it was, and still is, largely cut off from the wider world of data processing, and has followed its own path. Today it would be fair to say that GIS is entering the mainstream of information technology, but has some way to go. This separate development was fostered by computer hardware manufacturers who tended to stress the differences between general purpose and engineering computers in order to segment the market and create niches for their products.

The inter-dependence of engineering software systems, including GIS, with each other and with financial systems, was mentioned above. It is especially important that GIS should not be seen as a specialist system divorced from the normal workings of the organisation, because it is obvious from even the most superficial study that GIS data is used by almost every department within an organisation.

For example, Table 4-3 below illustrates possible use of spatial information within a typical local authority.

	Cadastral Map	Topographic Map	Master Plan	Zoning Plan	Utilities Plans	Road Plans
Planning	•	•	•	•		
Roads	•	•				•
Housing	•	•				
Traffic Police		•				•
Utilities	•	•			•	
Finance (Valuation)	•		•			
Marketing	•			•	•	

Table 4-3 The Use of Spatial Data in Local Government

4.1.3.1 Sub-Systems of GIS

According to general systems theory, systems are hierarchical. A geographic information system, like any other system, comprises a number of sub-systems. The most important of these are introduced below.

4.1.3.1.1 Data Conversion

4.1.3.1.1.1 Graphic Data

In the initial stages of establishing a GIS, data capture and conversion is a major area of activity. Organisations which work with maps have large amounts of information stored on paper maps. This has somehow or other to be entered into the computer system.

A base map comprising both topographic and cadastral data is a prerequisite for developing applications based on spatial data, and until the base map is available, applications cannot become truly operational. The production of the base map is almost always the responsibility of the national surveying and mapping authority.

In some cases the digital base maps can be purchased from the mapping authorities. However this is often problematic because very few, if any, authorities have managed to convert all base mapping to digital form. This leaves other systems developers in a quandary - should they wait for the mapping authority to produce the digital data they need, or should they go ahead and capture the necessary data themselves? The latter course is very wasteful of resources and may result in several organisations capturing the same data, but it is unfortunately all too common.

Life is no easier for the mapping authorities either, because they are under pressure to produce digital data for a multitude of customers who want data for many different areas and at different scales.

The cost of data acquisition is also an important factor. Agencies which have invested substantial sums in data conversion may not be prepared to supply this data free of charge to other agencies, and yet the pricing of data is a very complex issue. This can be seen from the number of studies on the topic and the radically different policies pursued from country to country.

These problems have been raised in order to stress the need for co-operation at national level between the creators and users of spatial data, in order to plan and prioritise the conversion of the base mapping. The private sector can also be used to meet the market demand for digital data.

Apart from obtaining the base map, the organisation building a GIS needs to convert its own data to digital form e.g. a planning authority has zoning plans, development plans, conservation area plans, road widening plans, height restriction plans, plans showing environmental constraints plus many more. These plans are authoritative with respect to the features that they are intended to show, such as land use zoning, road widening lines etc. However, they are not authoritative with regard to other features shown such as cadastral boundaries and topographic features. A careful map analysis has to be carried out to determine the features for which each map is authoritative. Map analysis will be dealt with in greater detail in Section 8.1.3.3 below, under 'System Design'.

When planning data conversion, several options can be considered, which apply to all types of map data:

Acquisition of Existing Digital Data

If digital data is available, whether it is free or not, the easiest route is to acquire this data. The main problem at the moment is the lack of data, especially in developing countries, although the amount of digital data available is steadily increasing.

Even when digital data is available, this is not the end of the problem. The data will generally be delivered in a different format from what the customer needs. This requires data conversion software, and experience shows that despite the promises of vendors, the conversion process seldom runs smoothly because it is extremely difficult to achieve an exact mapping from one system to another.

An example will serve to illustrate this. A company tendered to convert existing digital data to a new format for a South African city. They estimated the work to require a single workstation for a period of six weeks. Six months later, using eight workstations, the job was completed. It was then discovered that height data had been left out of the conversion. It may be said that this was the result of ignorance and incompetence, but humans form part of the system. A reliable system should eliminate as many opportunities as possible for human error and a quality control system should detect and correct those errors which do occur, as early as possible.

Other factors to be considered are the accuracy and consistency of the source data, in order to ensure that the data is suitable for the purpose for which it is to be used. To assess the accuracy one would need to know how the source data was obtained e.g. photogrammetric mapping, tacheometric survey, chain survey etc.; what the scale of photography was, what the scale of the original map was, who was responsible for the work, what control points the survey was based on, etc.

It is clear then, that, even when digital data is available, a data conversion sub-system must be set up to plan, implement and control the quality of the conversion.

Re-mapping

This is generally not a viable option for an entire country because of the costs involved. Nevertheless, for smaller areas such as a town or city, digital photogrammetric mapping is the ideal way to capture the topographic base map, particularly if the existing mapping is known to be out-of-date.

Photogrammetric mapping is, in effect, another way of digitising data, and therefore, before photogrammetric data capture is undertaken, the database design should be completed. If the mapping (i.e. digital data capture) is done first, a second phase of re-formatting the digital data is unavoidable.

Scanning and Vectorising

With suitable hardware, scanning represents a fast method of data capture. However the data cannot be used in a vector-based GIS until it has been vectorised. Automatic vectorisation is still far from perfect and the result needs a great deal of interactive editing which is generally not cost-effective. If the original colour separation sheets are available, the situation improves, particularly in respect of contour lines. These are very difficult to digitise accurately especially in steep terrain, but scanned contours can be vectorised automatically fairly easily if there is no other information on the map sheet.

Semi-automatic raster to vector conversion makes use of the algorithms used in the automatic process, but as soon as an ambiguity arises, the operator is prompted for input. This in effect combines automatic vectorisation with editing in a single operation. Because the operator controls the vectorisation process, the whole operation is more efficient and produces better quality data.

Tablet Digitising

The conventional method of data capture is by tracing the original map placed on a digitising tablet. This is a labour intensive task and is a more cost-effective method of data capture in low-wage countries. Provided that appropriate quality control measures are implemented, this is also a reliable way of capturing data. Areas containing a large amount of detail, for example contour lines in a mountainous area, cannot be handled effectively in this way - the semi-automatic method described below is much more effective. There is a trend for digitising bureaux based in low-wage countries such as India or China to undertake data capture for organisations sited in high-wage areas such as Western Europe or North America.

On-screen Digitising & Semi-Automatic Raster-Vector Conversion

On-screen digitising represents something of a compromise between scanning and the use of the digitising tablet. The map is scanned. The raster image is then used as a back-drop on the computer screen on which the various features are traced.

On-screen digitising can be combined with semi-automatic vectorisation. In this case the operator selects the various linear features on the scanned image and the system automatically traces the feature. When any uncertainty occurs, the system prompts the operator to select the correct feature. An example of this type of software is SAMI from Universal Systems Ltd. (USL). The software produces digital data in the format used by USL's CARIS GIS software.

The **data conversion** sub-system is dependent on the GIS data analysis and database design because this specifies what data is to be captured, and how it is to be formatted. For this reason **data conversion cannot start until the database design has been completed**. This point is stressed because many system developers, wanting to get as much data into the system as possible, as quickly as possible, start data capture before designing the database. The result is the expenditure of much time and effort in re-formatting the data later. The possibility of failing to capture important data elements also exists.

Another important point when planning data conversion is the assigning of priorities to various areas and data sources, so that the maps used most frequently are captured first, and those which are seldom used are left till last.

The data conversion sub-system has a major role, and uses substantial resources, in the early stages of system development. However, as more data is captured, the importance of the sub-system decreases until finally the task is completed and the system is no longer needed. One may say that the task is never completed, but once the GIS is operational, normal work procedures will keep the organisation's own data up to date. For example, in a planning application, if the master plan has been captured and the GIS has gone 'live', then any subsequent change to the data, such as a successful re-zoning application, will be made automatically during the operational procedure.

Quality assurance is just as important with regard to data conversion as in other areas of GIS development. The user of the data needs an indication of its accuracy and the confidence that the capturing process has not introduced new errors. Various checks can be used. These include logical checks of data and topology e.g. a coast line can be bounded on one side only by the sea; polygon features must be closed, etc. Mistakes can be detected by inspection by overlaying check plots on the original maps. If data is to be captured by digitising, suitable procedures should be written to simplify the task as far as possible for the operator e.g. functions selected by menu to set the correct drawing attributes for each particular map feature.

An important factor governing the long-term success of the GIS is the usefulness of the data. To be useful, the data must be relevant (covering the right area with the appropriate accuracy and amount of detail) and reliable (correct and up-to-date). Users <u>cannot</u> work with irrelevant data, and <u>will not</u> work with unreliable data. Thus serious attention has to be given to the design and implementation of the data conversion sub-system to ensure that it produces reliable and trustworthy data and to prioritising the data to be captured to ensure that it is relevant to users.

4.1.3.1.1.2 Non-graphic Data

In many geographic information systems the volume of non-graphic data may exceed that of the graphic data. However, the handling of this type of data poses far fewer problems than that of graphic data because the structure of the data is very much simpler, and because the handling of this type of data has become routine. Nevertheless, new technology is creating opportunities for capturing non-graphic data which was not included in older file-based or RDBMS-based systems.

There are three main classes of non-graphic data: tabular data, free text and document images. Tabular data is the kind of structured data which is entered on forms and stored in relational database tables. Capture of this type of data is quite straightforward. Quality assurance is usually provided by entering the data twice and comparing the results. When the data is already in digital form it is normally a simple matter to reformat to the format required by the new system. Problems do occur though, when digital data is stored in an obsolete proprietary system with no facility for data export. For example, the Registry of Vehicles in Singapore had several million vehicle records in a system for which the manufacturer no longer existed. There was no provision for data output other than to the printer. To convert this data it was necessary to use a PC to capture the output from the printer port, save the data in a file and then reformat the data.

Free text data is unstructured and is contained in reports, articles, books etc. This data is seldom captured directly from paper originals, but if word processor files are available, the data can be added to a database on which a free text search engine operates. Source material on paper can be scanned to obtain an electronic image. If the original is printed or typed and is in good condition on clean pages, it is possible to use optical character recognition (OCR) software to convert the image to text.

Document images are often not converted to text; instead the electronic images are stored on a central server where they are indexed and accessible to all users connected to the network.

4.1.3.1.2 Data Maintenance

Data maintenance is the term used to describe the process of keeping the data current. The organisation's own operational data remains current through on-going updates from the transaction processing system. For example, the processing of a re-zoning application will automatically alter the zoning plan to reflect the new situation. Other data, particularly that obtained from outside sources, must be kept up to date. GIS tends to make more use of external data, both graphic and non-graphic, such as topographic or cadastral maps, land registry data and socio-economic data. It may be possible to have on-line access to the agencies producing these various types of data, in which case the data will always be authoritative. At present this is seldom possible, chiefly for administrative and political reasons, but the trend is towards more on-line availability of data. In other cases external data sets should be updated regularly with a frequency corresponding to the rate of change of the data.

The agency responsible for producing the topographic base map has the biggest problem. Topographic maps show the form of the land (heights, contours, water courses), communications (roads, railways, canals, telephone lines), cultural features (buildings, settlements, land use), and so on. Because there are always countless changes to the topography which are not documented in any system a data maintenance, or map revision, sub-system must be set up.

During data capture daily operations cannot be suspended - life must go on as usual. Changes will occur in data which has been captured before the new system becomes operational, hence special arrangements must be made to track changes taking place during the transition period, and to incorporate these changes in the database. For example, the data conversion process may include the digitising of cadastral noting sheets. During the period between the digitising of a sheet and the system becoming operational or going 'live', new sub-divisions may be registered which change the data already converted. These changes must be incorporated into the new digital data before the system becomes operational.

4.1.3.1.3 System Administration

An open system requires continual interaction with the surrounding environment in order to maintain its internal equilibrium. Part of this interaction is handled by the **system administration sub-system**. This sub-system does the housekeeping for the GIS, performing tasks such as:

Adding and removing users
Controlling access rights
Hardware maintenance and repair

Software maintenance and fault reporting
Ensuring data security through systematic backup of data

It has been stressed that GIS must be seen as a sub-system of a wider integrated management information system. In this environment it is desirable that a single system administration should manage the whole system. The system administrator however, will require knowledge of the GIS software and of specialised peripherals such as scanners, plotters, and graphic workstations.

4.1.3.1.4 Applications

Traditional GIS applications are in the areas of:

- land planning, management and development
- land ownership
- taxation
- facilities management
- environmental protection
- agriculture and forestry

New application are being found in fields like

- marketing
- land valuation
- mineral exploration
- traffic management
- vehicle routing
- vehicle fleet control
- insurance risk assessment and management

While each of these fields has its own specific requirements, there are broad requirements common to all systems. General requirements would include a database in which the whole area of interest is represented by a continuous map, a user-friendly customisable graphic user interface, ability to handle vector and raster data together, open interfaces to peripherals such as scanners, digitisers, plotters etc., and a procedure language to enable the system to be tailored to the customer's needs. A specific requirement might be a special data element to represent an electric cable, or a function to generate pie-charts for thematic mapping.

Modern GIS software is converging. There is less and less to distinguish one vendor from another in terms of software functionality. In fact the developers are being driven by the market to produce what customers or potential customers are asking for. At present each software package has its own strengths and weaknesses, but there is no doubt that an organisation can develop a system suitable for his needs using any of half a dozen or more software products.

GIS software 'out of the box' is essentially a set of tools with which an application can be built. It is the way this building process is handled that determines whether the system will be considered successful.

4.2 The Corporate Information System

From this viewpoint the computer system is no more than a tool to help the organisation to do the things it does better. For example, managers potentially get more accurate information to support decisions and get it quicker, and better quality letters are sent out more quickly than before. More than twenty-five years ago Beer and other writers came to the realisation that the organisation with a corporate information system is not the same organisation it was previously, but this realisation has been slow to spread amongst corporate executives.

In the past five years the pressures of the 'global market' have led firms all over the world to examine what they are doing and see whether that can do it better. This accounts for the popularity of books on new management techniques such as 'business process re-engineering' and 'total quality management'. These techniques have been around in the academic domain for many years under various guises such 'system analysis' and 'organisation and methods studies', but are now being popularised by authors more attuned to the mass market. In addition, computer technology has advanced to the stage where every employee can have a powerful workstation on his desk. This provides the tool which enables many of the new techniques to be used .

The computer-based information system or corporate information system is a complex system comprising both human and electronic sub-systems. Davis and Olsen (1984, p.6) define the management information system as:

"An integrated user-machine system for providing information to support the operations, management analysis, and decision-making functions in an organisation. The system utilises computer hardware and software, manual procedures, models for analysis, planning, control, and decision-making, and a database."

Information systems are generally considered to operate at three levels in the firm - policy-making, executive, and operational. In Beer's systems terminology (see pp.2-18), policy-making corresponds to planning, and decision-making (*Systems 4 & 5*) in the *innovation* domain. The executive level corresponds to the monitoring and control function (*System 3*), and the operational level corresponds to operations and co-ordination functions (*Systems 1 and 2*), both in the *added-value* domain.

This correspondence is shown in Figure 4-4 below.

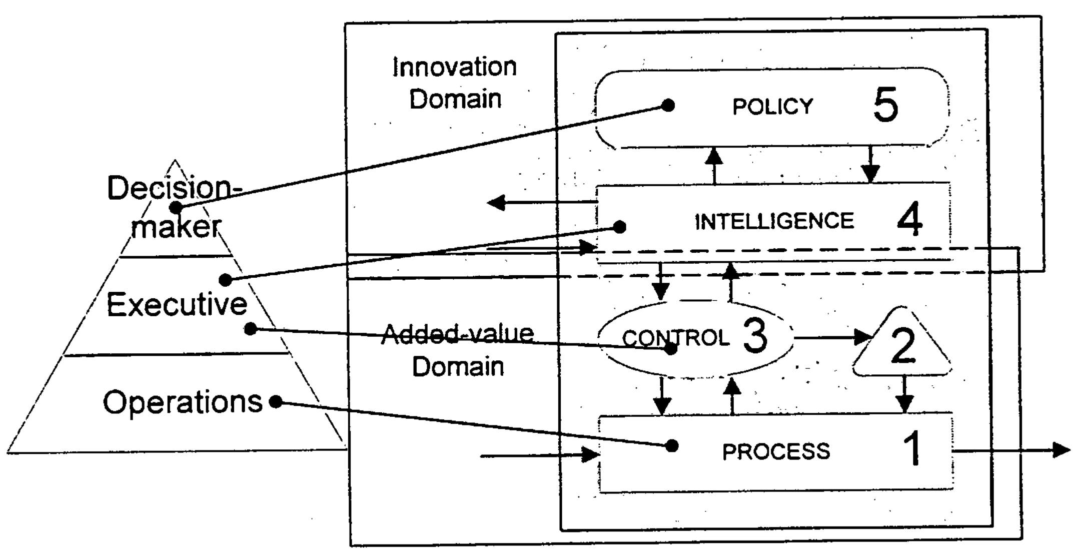


Figure 4-4 Relationship between VSM and Information System

Davis' definition covers all the main features of a computer-based information system. The geographic information system must be seen in the context of the corporate information system as a specialised sub-system which makes extensive use of spatial data as well as alpha-numeric data. Other types of data (multi-media) including images, sound and video are now beginning to be a part of the corporate database. It is only a matter of time before spatial data too becomes an integral part of most databases.

In contrast, current practice is to view 'GIS' as a unique discipline outside the scope of corporate information systems - perhaps a branch of surveying and mapping rather than a branch of information technology. Geographic information systems do indeed differ from other complex information systems in at least two important ways:

1. In addition to alpha-numeric data, the system stores spatial data. Management and manipulation of this data, including the representation, storage, indexing, retrieval and analysis, presents technical challenges
2. Spatial data is generally only meaningful in relation to other spatial data e.g. the information about the position of a sewer network becomes relevant when it is seen in relation to roads, topography, land use, cadastral boundaries etc. This additional information is collected by a number of different agencies. In other words, a GIS is usually dependent on data produced and maintained by external organisations. Most other information systems do not rely on external data sources to anything like the same extent, though there are exceptions such as economic intelligence systems which collect economic data from many sources and integrate the information.

These factors affect the management of the system, the hardware and software used, the technical skills needed and the acquisition of data. Nevertheless, from a functional perspective the GIS is simply a part of a complex information system which handles spatial as well as non-spatial data. The systems approach to GIS stresses the integration of GIS with the corporate information system.

4.3 The Role of the Information System

Figure 4-5 overleaf illustrates the integration of the components of a viable system with a corporate information system.

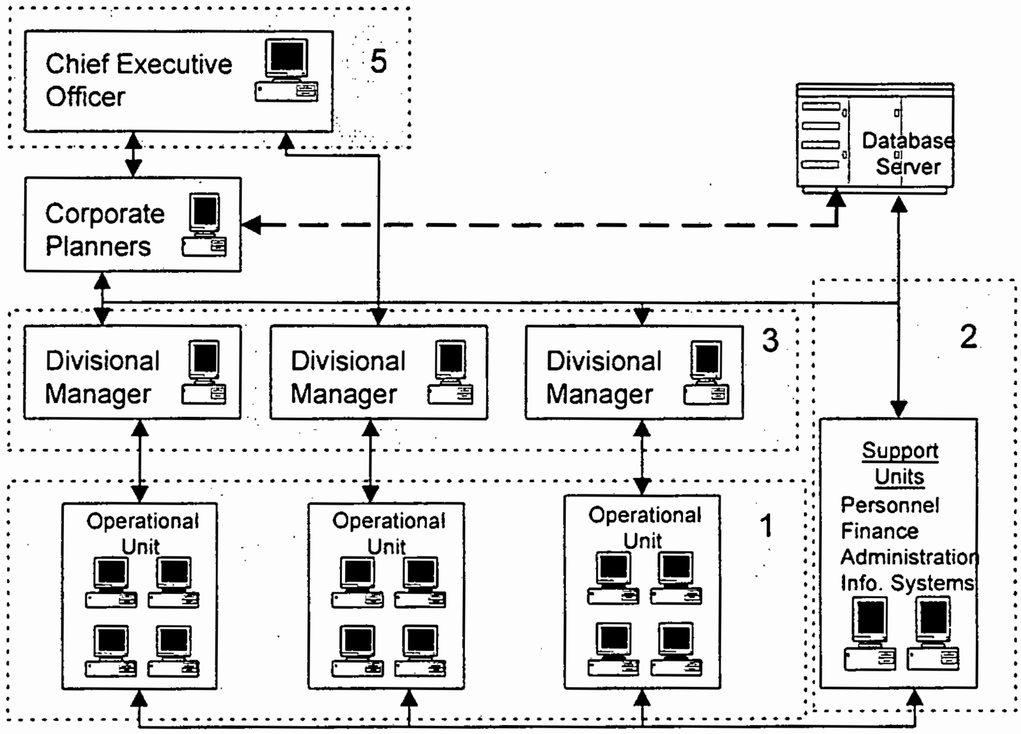


Figure 4-5 VSM and Information System

The information system fulfils three major functions within the organisation:

- **Communication**

  It has already been mentioned that information is the life blood of the organisation. Information flows in written form as letters, memos, reports and in spoken form in meetings and telephone conversations. The computer network provides links between all members of the organisation, enabling messages and data to pass almost instantly between co-workers.

  Electronic links to the outside environment are now becoming very important with e-mail and EDI (electronic document interchange) widely used for communications between the organisation and its customers. Figure 4-6 overleaf shows the communication links.

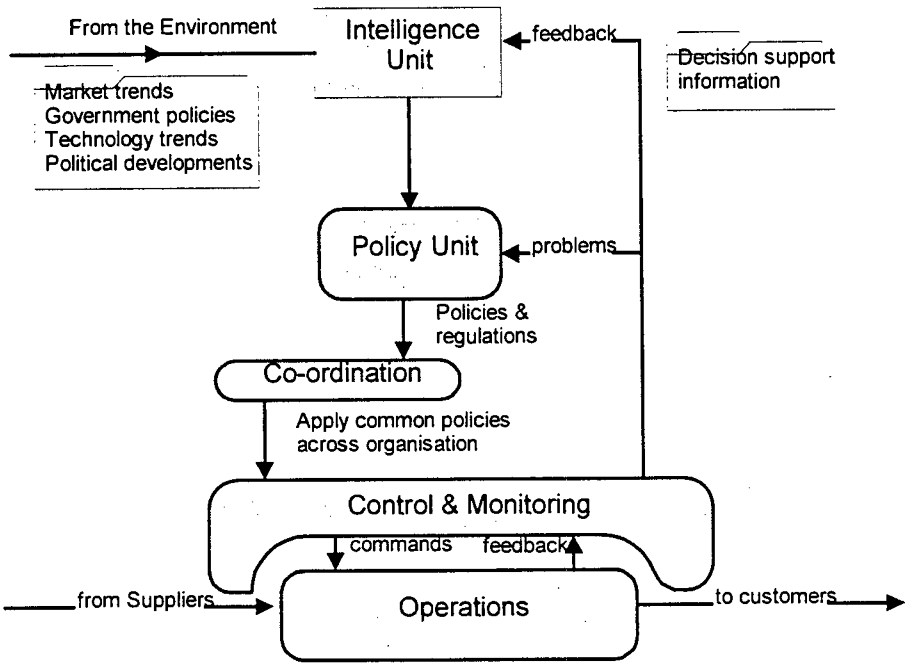


Figure 4-6 Viable System Model of the Organisation

- **Data Storage**

  The corporate database provides the means for every member of the organisation to access the information he needs to do his work. Databases no longer need to be situated on a central computer. They can now be distributed across several computers. This enables the department producing the data to be physically in charge of the data. Databases are the electronic equivalent of the central registry where all files are kept. Electronic access means that a number of officers can view the data simultaneously, whereas a file can only be viewed by one person at a time and may take an hour or longer to retrieve.

- **Data Processing**

  Many operational functions perform data processing by adding, deleting or amending data records. Some functions are simple, such as adding a new address record, while others may be much more complicated, for example creating a set of contours from a set of spot heights and adding these lines to a graphical database.

At this level the system is reducing the load on messengers by carrying more messages electronically, supplementing the filing system by allowing data to be stored in electronic form as well as on paper and speeding up some processes by using the computational power of the computer. This is not really innovative - existing processes are being done better with the help of new technology.

4.3.1 Data and Workflow

The innovative challenge is to involve the computer in the running of the next upward recursion level of the system, at the level where the co-ordination between departments and allocation of staff to tasks takes place - in other words to use the computer to manage workflow.

Workflow management is, in essence, a meta-program which controls a work system. The work system comprises manual and computerised tasks, paper documents and electronic data. The meta-program controls the allocation of each incoming job, routes the work from one official to another depending on the circumstances and monitors the state of the process, triggering alarms when abnormal conditions occur.

The effectiveness of workflow management is greatly enhanced when all data is in electronic form. Data transmission is no longer dependent on messengers carrying files around the building and possibilities open up for parallel processing of some tasks. The conversion of paper documents to electronic images by scanning has opened up this possibility. According to the systems view of organisations, the resource flow is the medium through which the organisation interacts with the environment to preserve its internal equilibrium. An important part of these resources is data. As data passes through the organisation it is checked, added to, transformed, stored etc. by the different officers who handle it. The primary function of the computer-based information system is to assist with these various data processing tasks in order to increase productivity. This flow of data, together with the tasks performed on it, is commonly referred to as **workflow.**

The clearest way to explain the concept of workflow is through an example illustrated in Figure 4-7 overleaf. An industrialist wishes to open a factory in a special development zone to make domestic electric fittings. He requires about 1 ha of serviced land. A small part of the procedure might be along the following lines:

1. Developer submits application to the Administrative Section.

2. Application is registered and a file is opened.

3. File is passed to Business Development Unit for examination of business plan. Does the proposal appear to be economically viable? How many local people will it employ? Are the marketing aims in accordance with the aims of the special development zone? If the application is rejected at this stage, the file is returned to the Administrative Section for the issue of a letter of rejection. This may trigger an appeal procedure. If the application is approved, the file is passed to the Planning Unit for the next step.

4. The planner looks for an unallocated site which meets the investor's requirements in terms of size, terrain, location and services. If a suitable site is available, the file is passed to a draftsman in the Survey Section.

5. The draftsman prepares a sketch plan of the site showing the location and approximate area. The plan with the file is returned to the Administrative Section.

6. An officer in the Administrative Section calculates the deposit to be paid by the investor and prepares the 'in-principle' approval letter. The file with the approval letter is passed to the officer's supervisor.

7. The supervisor checks the plan, calculation of the deposit, and in-principle approval, and hands the file to the Chief Executive.

8. The Chief Executive signs the in-principle approval and returns the file to the Administrative Section.

9. The approval letter is sent to the investor with the sketch plan and an account for the deposit.

10. The investor sends in a letter accepting the conditions of the lease together with his deposit.

11. The letter and cheque are received in the Administrative Section. They are attached to the file and sent to the Finance Department.

12. In the Finance Department the cheque is banked and a receipt is issued. The file is returned to the Administrative Section.

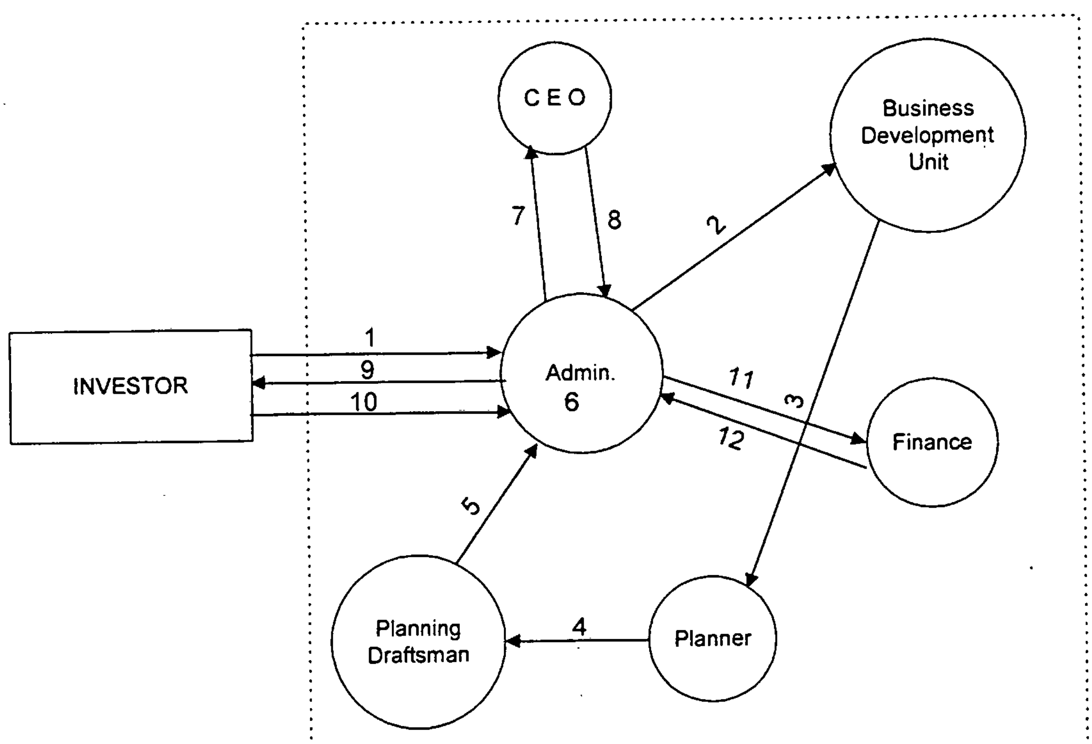


Figure 4-7 Workflow for Land Allocation

Figure 4-7 shows how the file moves between the various departments during the course of the process. The application spends most of the processing period either in the IN or OUT tray of the various officers who handle it, or with a messenger being carried from one officer to another. It is in this area that big increases in productivity are possible, through using electronic mail and imaging technology.

Through analysis of the workflow it is possible to identify the various tasks comprising a particular job, the sequence in which each task is performed and who performs each task. Once this has been done jobs can be computerised.

Computerised workflow implies:

- that the data contained in the paper file be recorded in electronic form. Considering the land allocation example, when a new application is received a new database record is created to hold details of the application. This holds the name and other particulars of the applicant, a parcel number for the property linked to the geographic information system, annual rent etc. as well as a field indicating the type of job (application for industrial land in this case). The record will also contain links to image files which contain images of correspondence received from the applicant. Plans attached to the application may be scanned and stored as digital images, while relevant sections of the plans may be vectorised, either using the digital image file, or by digitising from the plans.
- that there is a meta-program which describes how the process is performed. This might take the form of a database table specifying each task, the sequence in which the tasks are to be performed and the officer responsible for each. Further tables might provide the names of alternate officers for each task and the names of officers who are not available (on leave, sick, away from the office etc.)
- that after each task has been completed and signed off, all relevant documents including images and references to database records will be transmitted **automatically** by electronic mail to the officer who is due to carry out the next task. He will also be notified by a pop-up window on his computer screen that a new job is waiting for his attention.
- that senior management can monitor the progress of every application because the job record is automatically updated each time the file moves to another officer. This makes for greatly increased efficiency as delays can be spotted immediately.

Workflow is intimately connected with the data because data is manipulated at every stage of the process.

The data itself is the major organisational resource. A large component of the data held by any organisation has a spatial component, although this may not be clearly recognised. The spatial nature of data shown on maps is obvious to everyone, but tables containing list of addresses, constituencies, districts etc. are not so readily seen to be have a geographic basis.

Geographic data is most conveniently related to topographic or cadastral base maps which are usually produced by national mapping departments. In the past these base maps have been produced as traditional paper maps, and organisations building geographic information systems have spent much time and effort converting this data to digital form. This has resulted in much duplication of effort and much unnecessary expenditure. There is a move now in many countries towards the establishment of National Digital Mapping Databases (see Peled 1993). A characteristic of these databases is the use of a standard format for the delivery and exchange of data, which is independent of any software vendor. The standard format is made meaningful by the use of standard feature codes defined in a data dictionary which forms a part of the standard. This data, when available, is combined with the organisation's own data to form its own spatial database.

4.4 Integration of Organisation and Information Technology

There are many ways to integrate information technology with the organisation. Checkland (1981, pp.318 et al.) proposes two systems approaches to problems, which he refers to as 'hard' and 'soft'. He regards the 'hard' approach as appropriate when the problems to be tackled are clear-cut and well-defined or what he calls *structured problems*. Problems of this type are common in engineering, where the system requirements can be completely specified. The 'hard' systems approach makes use of the various techniques of software systems engineering to develop the required system. This is the method which has been, and still is, applied to the development of the vast majority of information systems.

Almost twenty years ago Wessel (1979 p.4) wrote "*Unfortunately, some information scientists still seem to feel that information systems can be designed, developed, and implemented as if information, people, and electronic computers could be treated like little round balls on a billiard table, that the interactions among these could be determined by something like Newtonian mechanics ... but we are dealing with information as a social product within complex information* *systems.*", and he adds "*Information, information systems, people, and their organisations are social products.*"

Now that information systems planning is extending to the whole enterprise, it is necessary to consider carefully whether the 'hard approach' is still valid. The introduction of a corporate information system changes the nature of the organisation. Information is much more widely available and communication between staff members becomes very much more effective. The question is then, if the organisation will be altered by the incorporation of an information system, is it possible to specify system requirements in detail? Checkland's response to this (unstructured) problem was to propose the 'soft' systems approach.

Unstructured problems are those in which there is feeling that something is wrong, but there is no agreement on what is actually wrong, or on how it should be put right. The 'soft' approach supplies a methodology to develop a system specification, from which point on the 'hard' approach takes over. This approach to organisational change is described more fully in Chapter 5 (p.5-1).

5. ORGANISATIONAL ANALYSIS AND MODELLING

It has been shown that for the information system to be effective, a close integration between the human organisation and the electronic computer system must be achieved. To do this, it is important to design the system so as to match the requirements of the computer system with the requirements of the organisation. Because it is now much easier to customise a computer system than to change organisational behaviour, there is a strong tendency to tailor the computer system to the existing organisational practices. Unfortunately, this is unlikely to lead to the desired outcome of maximising productivity and efficiency. Stafford Beer (1981, p.16) writes "*The question which asks how to use the computer in the enterprise, is, in short, the wrong question. A better formulation is to ask how the enterprise should be run given that computers exist. The best version of all is the question asking <u>what, given computers, the enterprise now is</u>.*" The same thinking underlies the 'soft' approach to development proposed by Checkland. That is to say, the introduction of a corporate information system implies changes to the organisation.

In recent years management research has focused on ways of changing companies to make them more productive and hence more competitive. This has been forced on many companies by economic globalisation bringing competition from foreign firms and by the privatisation of state enterprises which are then forced to compete for business.

Various ways of solving the problem of organisational change and renewal have been proposed including business process re-engineering, business process assessment, 'soft systems' analysis etc. The ideas behind the names are essentially the same, though the terminology may differ. Table 5-1 overleaf sets out the steps in the terms used by two authors, while Figure 5-1 also overleaf illustrates Checkland's approach.

It can be seen that the steps are by and large the same. Morris adds an eighth step which is to update the definition of the relevant system (Step 3) to reflect the new situation. This final step leaves one in a position from which the whole cycle can be repeated - what Morris refers to as 'dynamic re-engineering'. The transformation of the organisation becomes an iterative process. This is in fact the cybernetic control system introduced in Section 2.3 - feedback is used to redefine the system, which in turn controls the analysis and modelling process. Without this cycle, the organisation is like a navigator who plots the route to his intended destination, then points the vessel in the right direction and hopes to arrive at his destination without any more effort. On a long voyage currents and storms will certainly deflect the vessel from its true course and if regular position checks are not made, it is unlikely that the destination will ever be reached.

	Checkland 1981	Morris 1993
1.	determine existing situation	business activity mapping
2.	problem statement	identify key problem areas
3.	define relevant systems	identify core business processes
4.	build conceptual model	define alternatives, simulate new work processes and work flows
5.	compare model with existing situation	define the potential impact of each alternative
6.	determine feasible and desirable changes	select the best alternative
7.	action to improve the situation	implement the selected alternative

Table 5-1 Organisational Change and Renewal

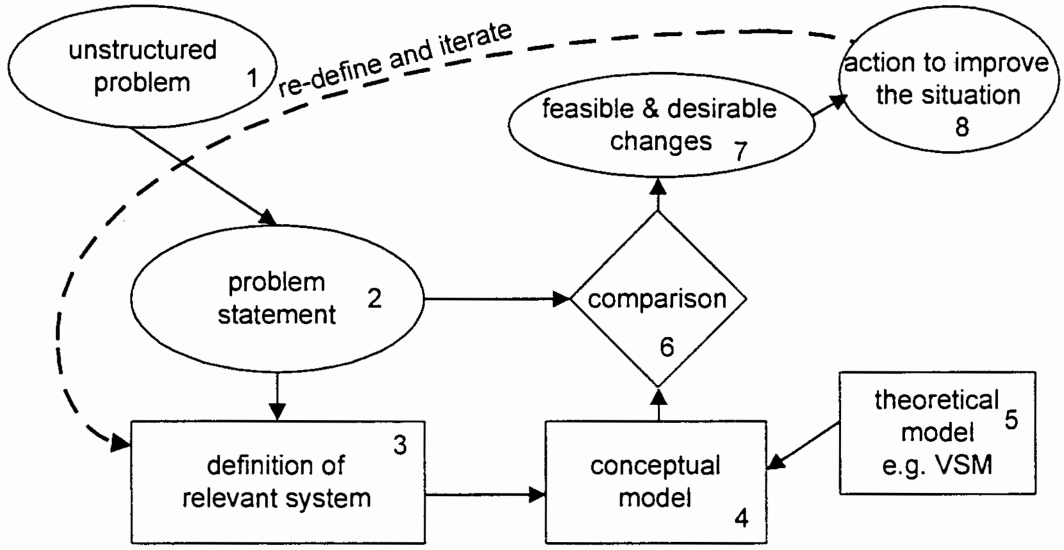


Figure 5-1 The 'Soft' Approach

5.1 The Starting Point - Where we are now

In planning a journey, it is necessary to know the starting point and the destination. A map is useful too. At the start the destination, or goal, may be a long way off and it may only be possible to describe it in broad terms such as "to increase productivity and improve customer service through effective use of information technology". At this stage the company suspects or believes that it may be possible to improve its performance, but has no idea what specific measures should be taken.

This situation fits exactly with Checkland's 'unstructured problem'. As one travels through the planning and design operation, the goals become clearer and can be specified in greater detail, until finally there is a detailed design from which the desired system can be built. There is a parallel with surveying - the landscape of business objectives and processes, of technology and information must be mapped and then the best route through the landscape must be selected and followed.

The planning process begins from the present situation - where we are now. This is seldom well defined, but can be investigated. A study must be done to determine what the organisation does, how it does it and to what extent computer systems are being used. David Patching (1990) makes the point "*...the exercise of thinking about the situation in these terms leads to a new understanding on what can or should be happening below the surface of the real world, why certain problems occur, and, as a consequence, how improvements can be made.*"

Modern commercial and government organisational structures are essentially western, but have been adopted all around the world. The relevance of looking 'below the surface' becomes very clear when working with organisations in which the western forms are imposed on a non-western culture. For example, 'wayang kulit' or shadow theatre is an important Javanese art form. Dramas are acted out by the shadows of puppets projected on to a translucent screen. There are three levels: the shadows actually seen on the screen, the puppets behind the screen, and the puppet masters. This three level view is carried over into the business world.

1 The shadows represents the contract or outward form of the deal.

2 The actual puppets represents the deal in its context of discussions and supporting documents.
3 The puppet-masters represent the underlying reasons for the deal and the actual work to be done.

A foreign businessman unfamiliar with the culture may very well mistake the contract for reality whereas it is just a shadow.

The 'hard' systems approach views the organisation as a rigidly hierarchical deterministic system which can be made more efficient by automating processes and communications. In suitable cultural environments this approach may work but always carries serious risks.

It is common, when embarking on computerisation, for management to specify that the computer system must support existing work practices and methods. In other words the 'existing' system, as documented in organisation charts and procedure manuals, is being implicitly adopted as the development model. The problem is seen as a structured problem (deterministic), that of computerising existing work practices. The job of the system analyst is then to study the existing functions and to produce a system to automate them.

There are historical as well as sociological reasons for this. In the early days of computerisation, computers were relatively inflexible, difficult to program and operated best in batch mode. It was possible to achieve productivity increases, but only by changing business methods to suit the computer. Forced changes created organisational problems and required expensive re-training. As computers became more powerful with better development tools, computer companies saw a competitive advantage in the sales line: "You don't have to change the way you run your business, we will build you a computer system to automate the way you do your business now". This has been referred to by Hunter as "*automating the mistakes of the past*" and he argues that to avoid this pitfall, operational procedures must be analysed with regard to how they should best be carried out given the availability of the computer.

As long ago as 1961 Daniel (1961, pp.112-113) wrote "*The key to the development of a dynamic and usable system of management information is to move beyond the limits of classical accounting reports and to conceive of information as it relates to two vital elements of the management process -*

planning and control ... information systems for business planning still represent a relatively unexplored horizon". In the years since that was written, the advances in computer technology have been phenomenal, but the basic mindset of the business community has not changed very much. A generation later a great deal still needs to be done to bring to the vast majority of business enterprises, small, medium, and large alike, the message that information systems should support all facets of the business, particularly planning.

The systems approach, and in particular the use of the viable system model, coupled with the 'soft' approach, can provide an effective way to avoid these pitfalls, and to design and build a successful corporate information system. The methodology will be developed in the following chapters. Here, the meaning of the word *methodology* should be clarified. The Collins International Dictionary defines it as "the system of methods and principles used in a particular discipline, the branch of philosophy concerned with the science of method." Checkland places it mid-way between a <u>method</u> which is very detailed and specific, and a <u>philosophy</u> which is too general to be of much practical help in problem solving. He writes (1981, p.162) "*A methodology will lack the precision of a technique but will be a firmer guide to action than a philosophy. Where a technique tells you 'how' and a philosophy tells you 'what', a methodology will contain elements of both 'what' and 'how'*". The word is used here with the latter sense - as a guide to system development from which an appropriate method can be derived to handle specific cases.

The information systems plan is an integral part of the business plan and should always be seen in this context. Information system planning cannot take place in isolation. This can be illustrated by an analogy with construction. In designing a building an architect has to take account of the physical features of the site such as the bearing capacity of the soil and the slope of the ground. If these are his only considerations, inappropriate buildings can be, and often are, erected. However, if all the environmental and cultural factors are considered, the result is a building in complete harmony with its surroundings.

Figure 5-2 overleaf suggests that the path from the present position to the desired goal is straight, but in there are many possible routes. Different priorities can be given to functions to be automated, different training focuses are possible, contractors can be used for data conversion, various hardware and software configurations may meet users' requirements etc.

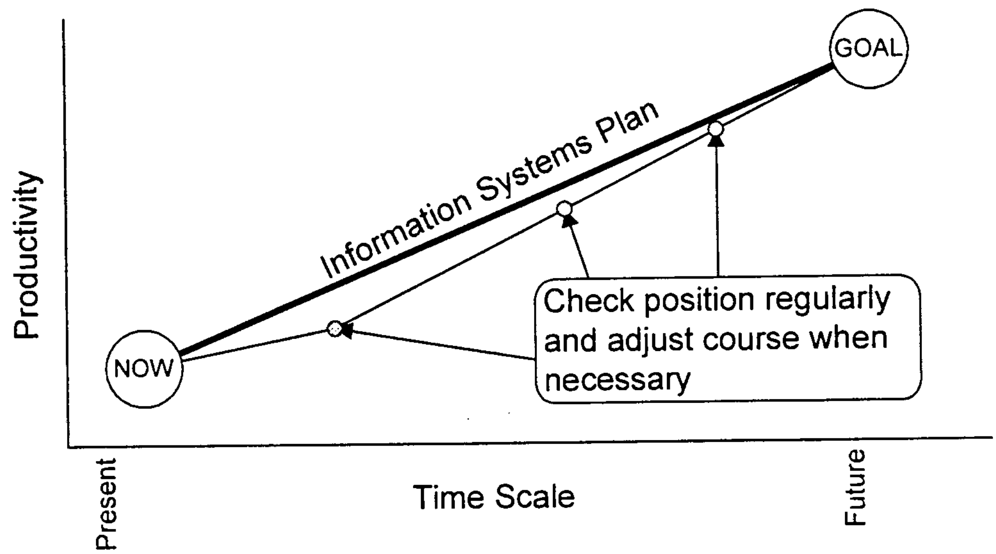


Figure 5-2 The Path to Organisational Transformation

Wessel (1979 p.27) suggests that time and effort spent on cost/benefit analyses for information systems would be better spent costing and evaluating different paths to automation in order to select the optimum route given the constraints of time, money and manpower, just as a civil engineer selects the route for a new road by balancing costs of construction and land acquisition against journey time.

5.2 The Business Model

The business model proposed here is patterned on the viable system model described above. A summary of the definitions given below may be found in Table 5-2 on page 5-10.

The key features of this model which is illustrated in Figures 5-3 on p.5-8 and 5-4 on p.5-9, are:

1. The basic element of the organisation is the individual who may fill several roles. An **agent** performs a **task** and may be an individual or a group of individuals.

2. The **task** is the basic unit of work done in the organisation. It is done by an **agent**. A **process** is sequence of tasks directed to achieving the aims of

the organisation. A **task** may form part of more than one process. Identification of common tasks can often lead to productivity gains.

3. The organisational unit, or *work system* to use Hoebeke's term, is a recursive hierarchy of viable systems. The viable system comprises five elements. These are, with numbering following Beer (see p.2-18) :
    a). *System 1* The processing element which does work by transforming inputs to outputs. (**Operator**).
    b). *System 2* The co-ordinating unit which specifies how the work is to be done and supplies support functions. At the top level this provides administrative functions such as finance and personnel management. (**Support**). It also provides process control for the operations units. This function is analogous to the autonomous nervous system of an animal. Routine processes are carried out according to a set of rules. Provided cases fall within the rules, all decision making is automatic and the decision-making or executive element is not involved.
    c). *System 3* The monitoring and control unit which compares the actual outputs with the planned outputs and adjusts the process to achieve the desired results. (**Controller**).
    d). *System 4* A planning unit which looks at new ways of doing the work and at changes in 'customers' (users of the outputs) requirements. (**Planner**). The planning unit is also involved in monitoring and control, but at a higher level. Instead of monitoring the outputs of the business process, the planning unit monitors the methods used to produce the output, comparing these methods with those used by competitors and new methods brought by innovative technology.
    e). *System 5* A decision-making and policy-making unit which authorises changes in process specification, monitoring and control functions, and work procedures.(**Executive**).

4. Communication channels are an intrinsic part of the model. Within the basic unit they form the means whereby the specification is made known to the processor, the controller gets feed-back on the output and adjusts the process, proposals are passed to the decision-maker and decisions are sent back for implementation. **Messages** transmitted from one element to another contain this information.

5. Every unit uses and generates information. Some of this information is needed by other units in order to carry out their tasks. This common information is stored in databases from where it is accessible to those who need it. Data can be regarded as any other resource - a database access is analogous to an indent on a store for physical material, or a request to a central registry for a file.

6. Any work system may own a **data store**. The system's tasks will include saving data in the store and retrieving data from the store. A control and monitoring function is needed to maintain the integrity of the data store and co-ordinating rules are needed to ensure that standard procedures are followed for data back-up, access control etc.

7. The work unit, or work system, is the system and at the same time a system component in a recursive hierarchy. An agent may belong to more than one work unit e.g. an individual may perform the control function in one system and may also be a member of the management committee supervising several other systems. He may carry out operational duties in *System 1* and planning work in *System 4*.

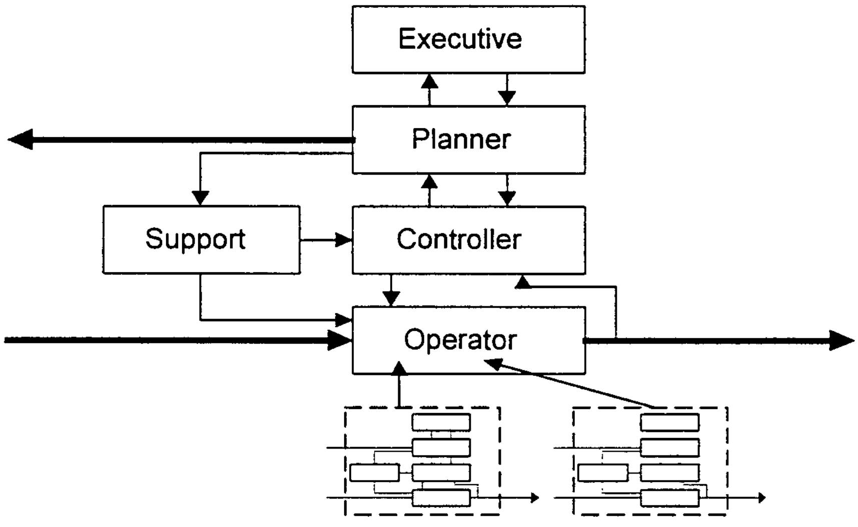


Figure 5-3 The Basic System Model

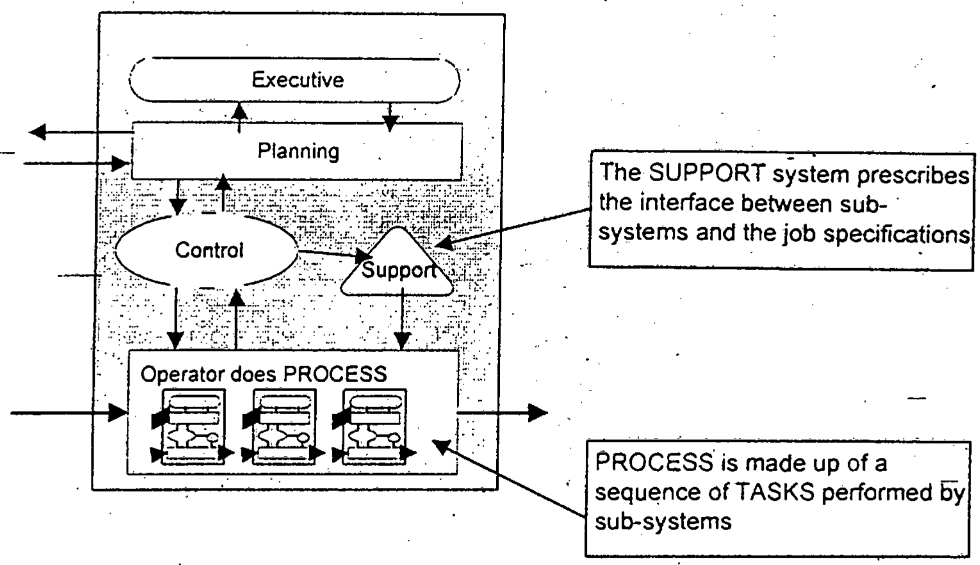


Figure 5-4 Details of the System Model

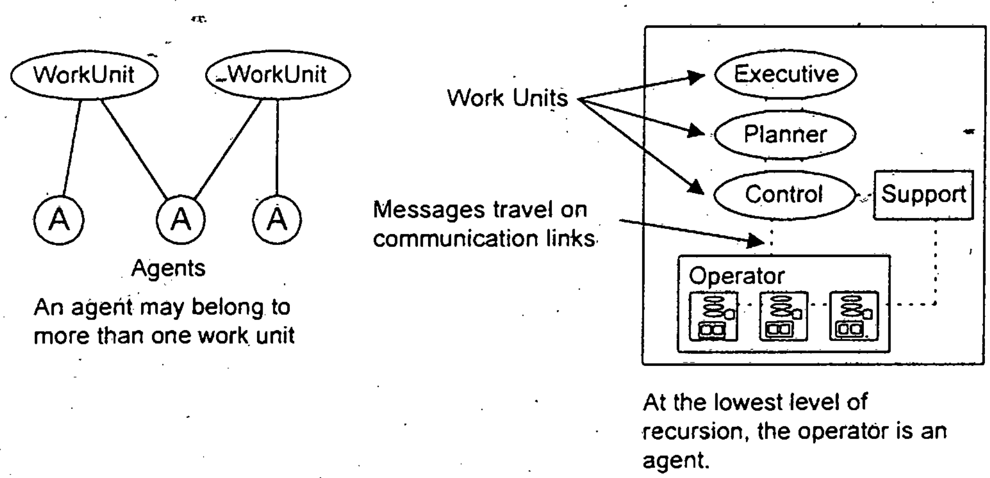


Figure 5-5 The System Model in Terms of Work Units and Agents

Summary of Definitions as used in Section 5.2:

Agent	An agent performs one or more tasks, and may comprise one or more individuals, and fulfils various roles.
System	A work system comprises agents and other systems as illustrated above. A system may ~~be~~ part of a system, and may contain sub-systems. A system comprises the following components: a) a functional component which performs a process to transform input into output. This component is a set of sub-systems. b) a control unit which monitors the output, and controls the process to ensure the output complies with specifications. c) an executive unit which makes decisions on issues outside the scope of the control or support units. d) a planning unit which monitors the external system environment to detect changes which will affect the process, and to formulate plans to deal with such changes. e) a support system which provides common services, regulations and operating guidelines to all operational systems.
Task	A task is a unit of work which is performed by an agent. Tasks can send and receive messages.
Process	A process is the operation performed by a system. A process comprises a set of tasks which may be represented by a directed graph .
Message	Messages are sent between tasks to initiate tasks, to convey inputs and outputs, and to signal various events.
Data Store	Every system has internal resources (Patching 1990, p.89). These resources will include information which is stored in a data store. This information may be kept under the direct control of the system, or it may be kept in central registry or data base.

Table 5-2 Definitions used in the Business Model

5.3 Analysis

Analysis can be understood from the same system perspective as the system which is being modelled. Figure 5-6 shows the pattern for the system performing the system analysis.

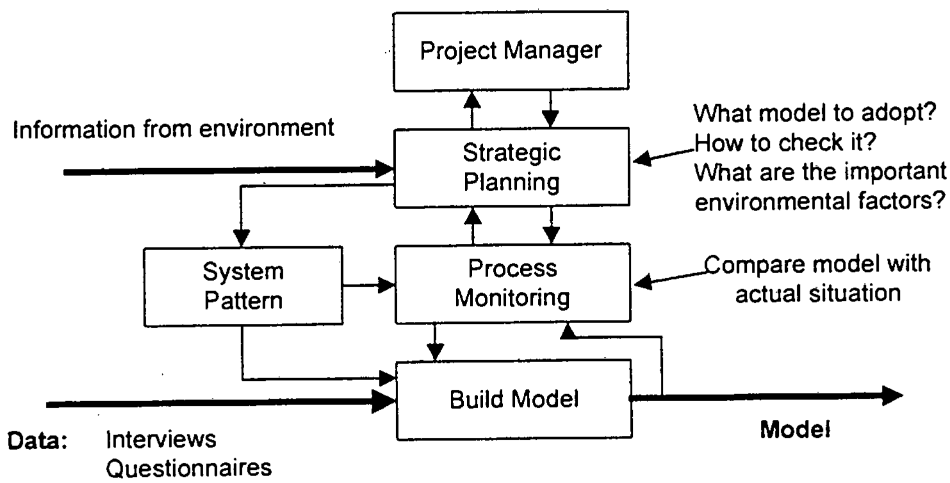


Figure 5-6 The System Analysis Work System

The design of the analysis methodology is a function of the super-system of the system performing the analysis. This task includes adopting an appropriate business model, planning what data to collect and how to collect it, determining how the data will be verified and how the model will be compared with the actual situation.

Analysis of a situation begins not with the organisation but with the **process**, in this case the system development process. Several questions have to be answered about the process:

- Who owns the process? In other words who is responsible for deciding to stop the process. This is the executive (*System 5*).
- Who carries out the process? Who is the operator who performs the various tasks - it may be a group of sub-systems.(*System 1*)
- Who monitors and controls the process? Who is the controller? (*System 3*)
- How is the process monitored? What outputs process attributes are monitored and how are they measured?

- What are the inputs needed to carry out the process? Where do they come from?
- What output is produced?
- What are the communication channels which carry the input and output?
- How is it produced? What are the operational steps needed to carry out the process?
- Who uses the output? That is to say, who is the client?
- What rules and regulations govern the process, and what support functions are needed? (*System* 2).
- Who monitors whether long term changes will be needed in the process, and how the process can be made more efficient? (*System 4*)

Once these questions have been answered, the structure of the system emerges. By repeating this analysis for each of the sub-processes, a model of the whole organisation can be built up. Mapping this model on to the formal organisation structure may reveal anomalies in the structure such as overlapping responsibilities, or tasks for which no-one is responsible.

This model can be applied to a commercial undertaking or government department for illustration as is shown in Figure 5-7.

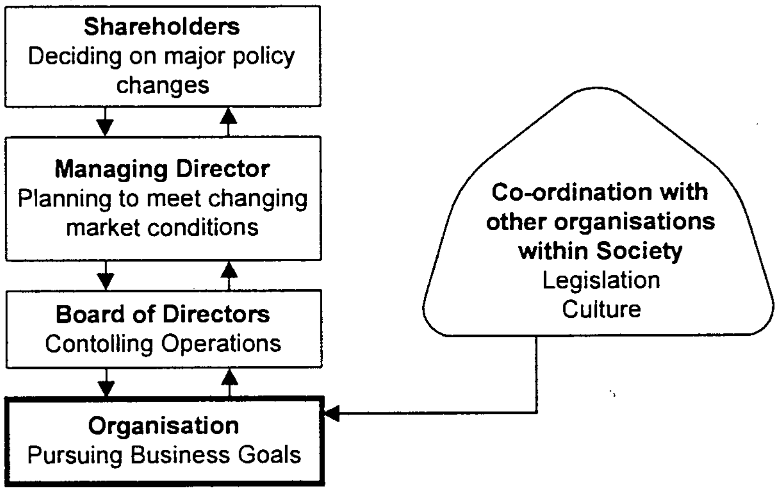


Figure 5-7 A Commercial Organisation in its Environment

The Managing Director understands the operation of the business, and is in the best position to collect relevant information both from the market and from the company itself. He has a responsibility to plan future strategy by preparing business plans in line with market trends. These are presented to shareholders for their approval.

The Board of Directors takes legal responsibility for the activities of the company, and has a duty of monitoring performance and initiating corrective measures when performance falls short of expectation. The Board is clearly external to the organisation because it may contain non-executive directors who have little connection with the day to day business.

The company operates in society along with a large number of other companies. Their activities are co-ordinated through legislation e.g. labour laws, anti-trust laws, price controls, import controls, taxation, enforcement of standards, etc., and through cultural forces e.g. response to advertisements.

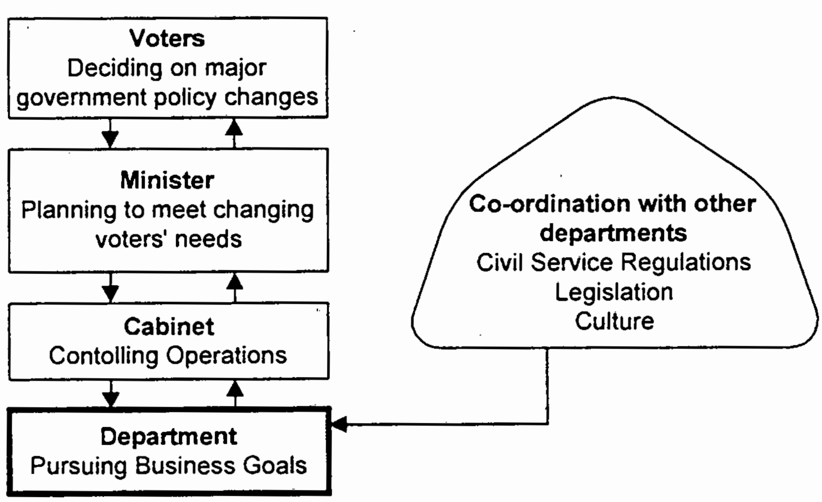


Figure 5-8 A Government Organisation in its Environment

Government departments can be viewed in a similar way (Figure 5-8). In this case the ultimate decision-making power rests with the voters (in democratic systems). Planning is the responsibility of the Minister in charge of the department, who corresponds to the managing director in the commercial world. The opposition spokesman on the departmental portfolio may also be considered part of the planning system as he formulates alternative plans which are put to the voters.

As the executive of government, the Cabinet is responsible for monitoring and controlling the performance of each department.

Finally co-ordination is achieved between departments through civil service regulations covering such issues as recruitment and conditions of service, and support departments such as finance, legal services etc.

5.4 Depth of Analysis

It is clear that there is a trade off between the depth of the analysis, or the number of hierarchical levels, and the amount of documentation generated, and hence the cost and time-frame for the analysis. The answer to this will depend on the circumstances.

It is essential to start with a high level analysis, going from the whole enterprise to the separate business unit, and to the business processes in each unit. The result of this analysis is an Information Systems Plan which provides a basis for developing an enterprise-wide information infrastructure by identifying common data sets and processes which span more than one business unit. Development can also be prioritised through revealing the dependencies between processes and data. Many if not most organisations skip this step on the grounds of cost, but finally end with a set of poorly integrated applications.

When actually developing the various application systems identified in the IS Plan, there is no choice but to decompose the business processes right down to atomic tasks which can be represented by computer functions. If documentation is to be worth anything, it must be complete and accurate. This is the only way in which it can serve its purpose of facilitating system maintenance and enhancement. It should be noted though, that there are various tools on the market which are able, at least partially, to automate documentation.

6. THE DEVELOPMENT ENVIRONMENT

Every information system is unique. Its development takes place in a unique environment which includes social, cultural, organisational and technical dimensions. Every company has its own corporate culture and every individual has his own unique personality and talents, though both exist within a wider cultural framework. This is the source of the enormous variety faced by system developers, wherein lie most of the problems encountered in system development. Kydd (1989, p.227) writes "*Many studies suggest that there are also serious barriers to success associated with the social or behavioural side of information systems development and implementation*" and refers to papers by Alter (1987), Edstrom (1977), Nichols (1981) and others.

6.1 The Organisational Environment

Two environmental factors are of major importance in information system development. The relationship between the various stakeholders in the organisation determines how existing power structures will be affected, and thus where and how much resistance will be offered to the new system. The degree to which computer technology is in use in the organisation has a major impact on users' reaction to a new system and on the role that they are able to play in formulating requirements for the new system.

6.1.1 Existing Computerisation

A major factor in the organisational environment is the extent to which information technology has been adopted and diffused throughout the organisation. When users are already familiar with computers and make use of them in their daily work, the introduction of a new system is seen as an improvement to the existing work system rather than an innovation. If, on the other hand, computers are not used, the introduction of a computer system represents a major innovation, and a discontinuity in the operation of the work system. Figure 6-1 overleaf shows the inverse relationship between the existing level of computerisation and the degree of difficulty in developing a successful system.

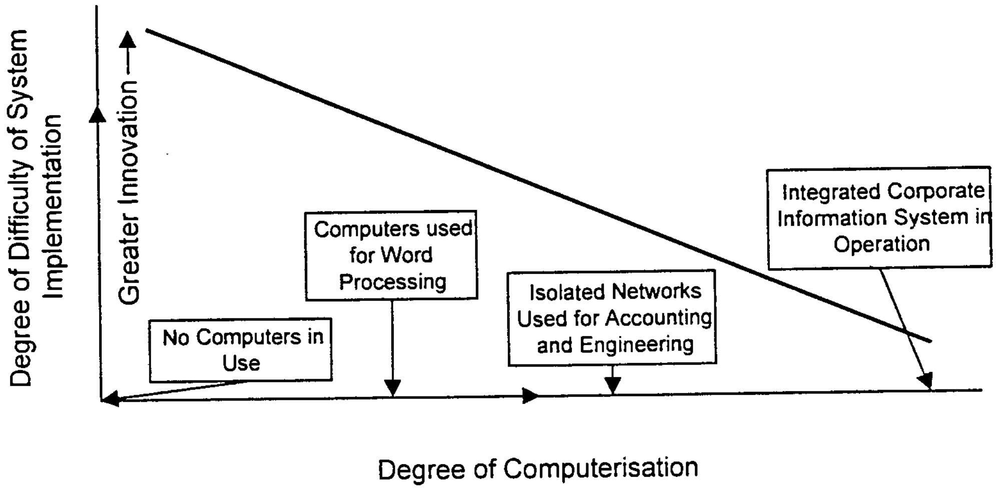


Figure 6-1 Degree of Difficulty Related to Degree of Innovation

In industrialised countries virtually all companies and government departments are computerised to some extent. There will be information technologists in the organisation and many employees will have some familiarity with computers.

In developing countries, in contrast, there are many organisations which have no experience with computers and others where computers are only used in a 'stand-alone' mode for word processing and accounting. It is in this environment that the challenge of system implementation is the greatest.

6.1.2 The Stakeholders

An organisation or work system has several groups of stakeholders who are affected by the development of a new information system. These include the employees, the board of directors and the customers, or in Hoebeke's (1994, p.16) terms the *actor*, the *owner*, and the *client* of the business process as shown in Figure 6-2 overleaf.

An individual may have more than one stake in the process, for example, he may be a system owner and a system user. Hoebeke (p.17) points out the danger of all three roles being taken by the same group of people. If the group specifying the process do the work and use the output, the system becomes a closed system and loses its viability. This danger arises in all specialist groups <u>including computer departments</u>.

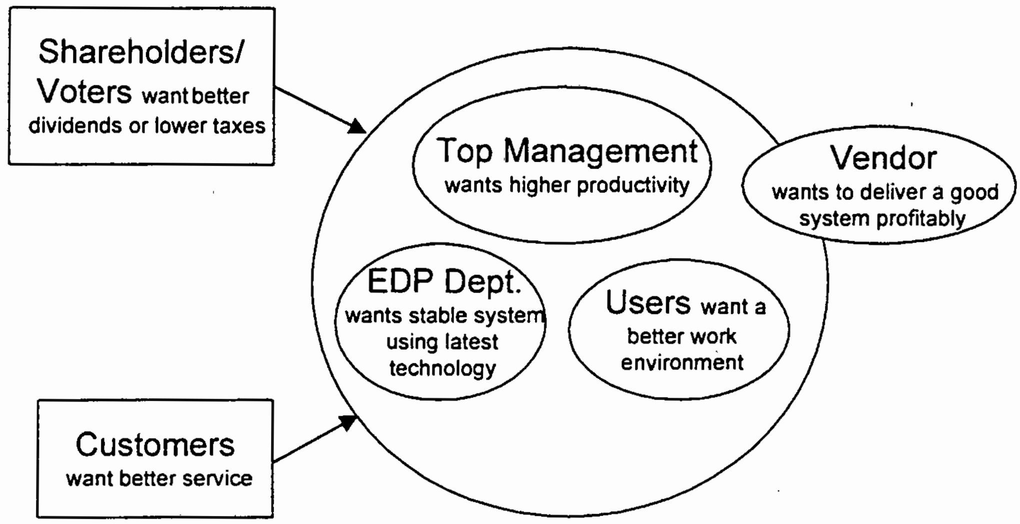


Figure 6-2 Stakeholders Who are Affected by System Development

A new information system has the greatest impact on the employees, or actors in the business process, because it inevitably changes their way of working. They are forced to learn new skills. They may also have fears about their job security and about their ability to handle the new technology. The users' support and acceptance is the single most critical factor in a successful information system.

As has been seen above, an organisation contains a number of sub-systems. Employees do not form a homogenous group, but operate in one or more sub-systems which include:

a). The Senior Management

Senior management form *Systems 3 and 5* at the top level within the organisation. It is their policy decisions which authorise the information system project and provide funding for it.

This group's primary objective is to achieve successful project implementation producing financial benefits which can be demonstrated to shareholders, or Minister and Parliament in the case of government, as quickly as possible. This role is illustrated in Figure 6-3 overleaf.

The active support of senior management is essential for a successful project because subordinates take their lead from their managers. If the managers are seen to be lukewarm to an information system project, enthusiasm cannot be created amongst developers or users.

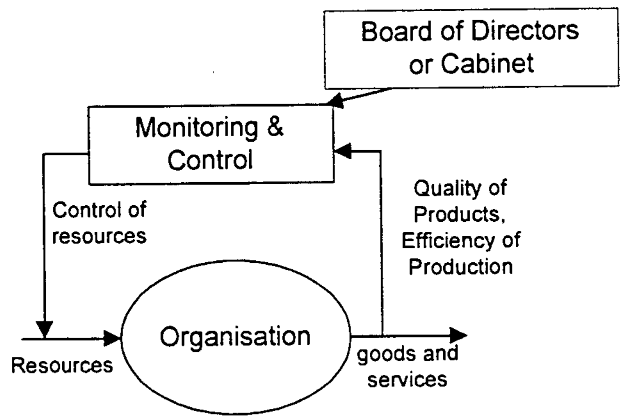


Figure 6-3 Senior Management is Only Concerned with Business Objectives

If the system is not successful it will not have a serious impact on the senior manager's career provided that he can show that he acted on reasonable professional advice when approving funds for the project. For this reason members of the senior management may not be fully committed to the project, or if they are initially committed, they may try to distance themselves from it if it seems to be going badly.

In the private sector, the activities of the senior management are monitored by the board of directors and shareholders assembled in general meetings. In the government, the activities of departments are monitored by the responsible minister and the cabinet. The monitoring system is concerned, or should be, with the organisational performance, not the means by which the results are achieved. However, in the government sector great store is also set by compliance with regulations.

b). The Management Level Initiating the Project

Project initiation and planning is a *System 4* function in the innovation domain. This group has several objectives which include

- the enhancement of its own performance through better reports based on more accurate and up-to-date information
- the enhancement of the performance of the department through better service and higher productivity
- a feeling of proprietary pride in the latest technology. Innovative project champions get a great deal of satisfaction from showing their project to visitors - this factor should not be underestimated. Large systems which are perceived to be successful receive a constant stream of visitors collecting information before embarking on their own system development.

This group has the largest stake in the project's success - they initiated it, got the budget to implement it, and supervised the development. Their careers would suffer if the system was to fail.

c). The Users

The third system is the users' group which may include the whole organisation. In practice users cannot be considered a single homogeneous group and must be sub-divided on a functional basis. As employees, users do not have a direct interest in the success or failure of the computer system. It affects them only in the performance of their duties, and they judge the system by the degree to which it facilitates their work.

The users have the least at stake in ensuring the success of the system, but are a key element in the success or failure of the system.

The system offers them the prospect of simplifying routine tasks which allows more time for creative or 'thinking' work. It may also offer analysis and production tools to enhance the quality of their work.

If the system is difficult to learn or use, it will be resisted by bottom-level users - operators and clerks. When the system disturbs established power structures, resistance comes from junior managers who see their authority being reduced or undermined.

Different groups of users will have different concerns. Users with previous experience of information systems will want a flexible and powerful system which they can use creatively to assist their work. Users without this experience will want a system which is easy to learn and operate and which is tolerant of incorrect input. Data processing staff will want to know if the system will be easy to maintain and modify. Trade unions will want to know what impact there will be on their members' job security and work environment.

d). The Customers

The company or department's customers expect quality goods and/or service, and may have the option (in the private sector) of transferring their custom to other suppliers. In most cases, customers have no direct input into the system design. However, when customers are direct users of the system, for example public information kiosks, automated teller machines, etc., the opinions of the public must be sought and incorporated into the design if the system is to find general acceptance.

The ATM provides a classic example of the need to understand customers. The first ATM's dispensed cash before returning the users' card. Many users took their money and went off without their cards. This caused inconvenience to banks and their customers and opened up opportunities for fraud. The problem was solved by making the dispensing of cash conditional on the card being removed.

e). Others

There are also other stakeholders such as the shareholders and the government. The shareholders are concerned that the financial benefits flowing from the use of the system will outweigh its costs. They have no interest in any details of the system, having transferred this responsibility to the Board of Directors and the company's professional managers. The managers bear the responsibility and will incur the ire of the shareholders if the desired result is not achieved.

Government inspectors may be required to monitor whether all necessary records are being kept for tax and statistical purposes, whether reports are submitted in the correct format etc.

6.2 The Technical Environment

The technical environment includes existing computer systems which may or may not be incorporated into the new system and, more importantly, the technical skills which are available both in the organisation and in the vendor/consultant's organisation.

Existing computing facilities represent a capital investment and should always be reviewed to assess the costs and benefits of integrating them with the new system.

Technical skills are much more important than hardware and software, particularly in the short term. A fairly complex system can be developed and put in place within a year, but the expertise to maintain and operate the system takes considerably longer to develop. Developing countries often make the mistake of relying too much on external expertise instead of developing indigenous technical capability. Employment of foreign experts does solve short-term problems, but long-term problems will remain unless local staff are learning from the foreigners - so-called 'technology transfer'. Foreign staff may present other problems. They lack familiarity with the local culture and language, and sometimes have difficulty relating to local officials on a personal level.

Training courses cannot produce skills overnight. Courses followed by years of 'hands-on' experience are needed to produce competent personnel. Experience in Singapore has shown that geographic information systems are introduced most successfully in organisations which have previously been using computer aided drafting (CAD) systems. The staff are already familiar with computer graphics and peripherals such as digitising tables and plotters and only have to learn the new GIS concepts of linking graphic and non-graphic data and spatial analysis.

From this it follows that an inventory of available skills is an essential part of information system planning. The information systems plan, apart from showing how information technology will be introduced to the organisation, should include an information system training plan which sets out a training programme to provide staff able to handle the system at each stage of its development.

It must be remembered that an important prerequisite for the successful use of a computer function is that its use be within the competence of the person who will be required to use it.

6.3 Project Inception

Someone has to take the first step towards the introduction of an information system. Major organisational changes seldom come about by chance. There is an individual who has a vision of what is needed and who then sets about influencing his colleagues. This person, no matter what his position in the organisation chart, is operating in *System 4* (Planning) in the innovation domain. Many people have innovative ideas but relatively few have the dedication and perseverance to bring their ideas to fruition.

According to Hoebeke (1994, pp.75-83), innovative projects have four attributes - desirability, feasibility, transferability and systemicity, which must be monitored. He writes (p.83) "*Innovations are best organised into projects and the project team members are the most adequate providers of these monitoring data.*"

Once an innovation has been suggested, the four attributes mentioned above must be monitored to see if the project can be implemented successfully. The innovator or project champion believes the project to be desirable, otherwise he wouldn't have proposed it. This isn't enough though. He must convince the key decision makers that the project is desirable.

6.3.1 Desirability

To establish the **desirability** of the project he must convince the key stakeholders that the project is necessary for the on-going success of the organisation. "*This is only possible if the innovators themselves have a passion to achieve what they desire*" (Hoebeke 1994, p.76). On the other hand it is equally important for policy makers to listen with an open mind to proposals coming from planning staff or staff operating in a planning mode.

The communication link between innovator and policy maker is often difficult because the policy maker is typically a mature, senior individual, while the innovator is bright and young, fresh from his studies and full of ideas based on the latest technology. On the one hand there may be an attitude of "We've always done things like this, and my long experience has taught me that it is the best way, besides I don't really trust new technology". On the other hand the attitude is "Management is so conservative, don't they realise that a GIS would pay for itself in one year, and thereafter there would be a steadily increasing flow of profits!" Provided an open dialogue can be maintained between these two points of view, the desirability of the system can be established.

6.3.2 Feasibility

The second attribute which an innovation must have is **feasibility**. Once policy makers have accepted the desirability of the proposal, the idea must be worked out in more detail to see if it is feasible. This applies as much to a computer system as to any other innovation. The protagonists of the system must persuade the other stakeholders that the project is feasible and that it will be successful.

The problem is that those defending the status quo know what they are defending, while those advocating change cannot guarantee that the changes will lead to better results. The advocates of change run the risk that their proposals may fail, consequently, in many organisations the people working in the innovation domain do not push their ideas too hard in case they are blamed for subsequent failure .

At this point whole-hearted commitment from the senior management to the project is crucial. By backing the project, the senior management (business process owner) accept the risk that the project may fail, but show a belief that the project is feasible and has a good chance of success.

Naturally, in order to persuade others that the project is feasible, the project group must first satisfy themselves that it is. This is done through investigation of available technology, studies of similar projects, and cost/benefit studies. Often a small pilot project is undertaken to demonstrate the feasibility of the proposal. This enables managers and users, who may not understand the technology, to see what the system will look like and what it will do. This is a powerful aid in establishing feasibility.

If the purpose of feasibility studies is to guarantee the success of the project, the studies will never be completed because success can never be guaranteed for an innovative project. Hoebeke (1994, p.77) points out that "*a bureaucratic culture where legitimisation and justification are more important than action, is not a very adequate environment for taking risks to start activities which intrinsically have no guarantee of success*". On the other hand bureaucrats and company directors are venturing taxpayers' and shareholders' money, and this should not be done recklessly.

6.3.3 Transferability

The third attribute, **transferability**, is measured by the degree to which an innovation can be absorbed in the value-added domain. The transferability of an information system will be indicated by the extent to which it becomes integrated into the business process functions (*System 1*).

Lack of transferability is a major cause of the failure of information systems. The project group may ascertain the users' requirements and develop a system which meets all these requirements in a test environment, but which fails to work in the real operational environment. Communication failure is at the heart of this problem. The project group is reluctant to transfer ownership of the project to the users, and the users are not sufficiently trained to operate and maintain the system.

Law (p.36) gives some examples of systems which failed through lack of transferability:

> "*a system was installed in one of the less developed countries which would have been a good one in the U.K. It failed there because the workforce was virtually illiterate; the right infrastructure did not exist to support computerisation*"

> "*a system installed in a factory failed because the shop-floor workers tended to hit the keys rather than press them. The equipment could not stand up to the handling it received*".

6.3.4 Systemicity

The fourth innovation attribute is **systemicity**. This reflects the degree to which the innovative system takes into account the operational system's interfaces with other systems and its environment. An information system must be designed from the perspective of the system in which it will operate. For this reason there can never be such a thing as an 'off-the-shelf' geographic or any other information system. It may be possible to find larger more flexible components on the shelf from which to build the system, but ultimately each system must be customised to the environment in which it will operate.

6.4 Project Development

Innovations typically follow a project format - they have a beginning at a point where the desirability is investigated, and an end when the innovation becomes part of the added-value domain and ceases to be an innovation. There will also be time and cost constraints. It has been argued above that the introduction of a computer-based information system is a major innovation, and as such, it should be handled by a project team.

At the beginning of a GIS project, the organisation usually possesses only limited expertise in the field. Even if there is an electronic data processing (EDP) department working with commercial and administrative applications, this group lacks the competence to develop a geographic information system. However, their experience in systems and user requirements analysis does provide a useful resource for the GIS project.

This lack of expertise can be handled:

a). by employing suitable experts on a long-term basis. The intention is that these experts will plan and develop the system, transfer it to the users, and thereafter maintain and improve the system.

This can work very well under suitable circumstances, for example in the State of Qatar, GIS has been developed by a team of (mainly) Canadian and American experts who are in the full time employ of the Qatar government. By retaining the experts on a long-term basis, technology transfer to Qataris can take place at their own pace. In poorer countries this is not a feasible solution unless local experts are available. Qualified foreigners have to be paid substantially more than locals; this often leads to friction and a breakdown in communication. To communicate effectively both parties must perceive themselves to be equal in status.

b). by employing a consultant company which will undertake system design and development, and will hand the system over on completion to an internal system support and maintenance group.

c). by employing a computer vendor to develop and install the system on a *turnkey* basis.

These two options are similar except that in the second case, the vendor has an interest in promoting a particular type of hardware or software. This is not a serious objection because no vendors today can provide a complete range of products to build a system. e.g. Siemens have supplied GIS built with CARIS GIS software from Canada, Informix database software from the USA, and Silicon Graphics workstations from the USA. Digital Equipment Corporation have supplied a major GIS in Singapore using ArcInfo and Oracle software on a DEC hardware platform. 'Independent' consultants too have their personal preferences and links to hardware and software vendors.

Consequently three groups are generally involved with the system development. These are the organisation implementing the system, the consultant/vendor company, and the project team drawn from members of the other two groups.

The interaction of these three groups determines how the organisation adapts to a new system, and plays a large part in determining the outcome of the system development project.(see Demb, pp.148-150, et al.)

The consultant company has interests which conflict to some extent with those of the target organisation. The company aims:

- to make money through sale of hardware, software, and technical expertise.
- to build a long term relationship which will produce a steady income through system maintenance and upgrades.

The consultant has a divided loyalty. He must think of his company's profits which after all pay him, but at the same time must deliver a good working system which can be used as a reference site to win further business. His best interests are therefore served by doing a good job at a fair price.

A foreign consultant may not be interested in a long term relationship, but may want to get as much money out of the project as quickly as possible. Where possible, local consultants, systems integrators and developers should be used because they are much more likely to be willing and able to provide on-going system support.

It can be seen that the external consultant and the senior manager within the organisation have broadly similar aims - they both want to see the project brought to a successful conclusion. The way to achieve this aim is to establish a project team which unites the consultant's expertise with the organisation's business knowledge.

It is important to co-ordinate and align the aims of each group so that each sees the <u>same</u> objective (the so-called win-win situation). Figure 6-4 below illustrates the conflicting requirements faced by a project team when an external vendor or consultant is used. There is a responsibility to the customer organisation to deliver the contracted system, and there is a responsibility to the vendor or consultant organisation to deliver the system at minimum cost. The composition of the team and the way it functions has a direct bearing on how the conflicting requirements can be reconciled.

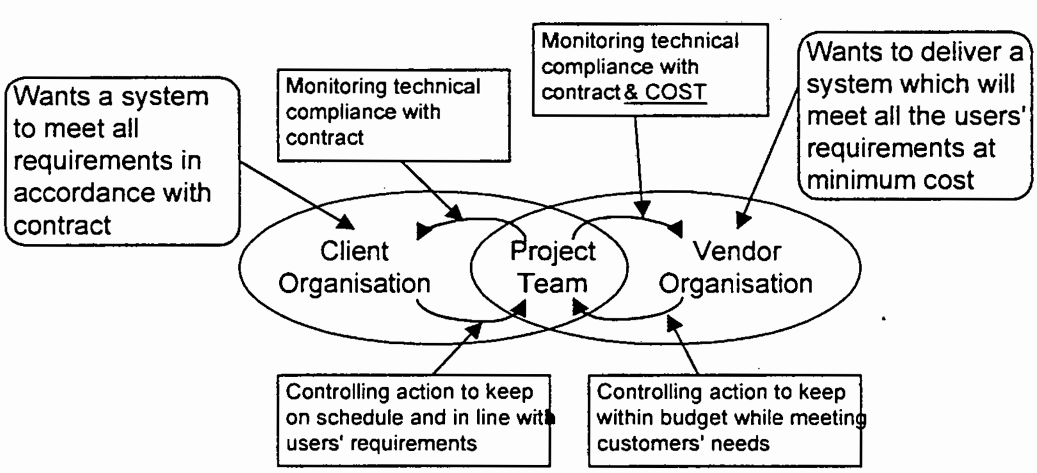


Figure 6-4 Conflicting Aims of Project Team

The external consulting firm have to interact with the customer organisation. While, in large measure, this boils down to interaction between individuals, organisations have a group culture which affects the conduct of individual officers. Lee (1987, p.104) calls this the organisational style and depicts it using a 'style triangle'.

He bases style on three factors:

- structure ranging from homogenous to heterogeneous
- politics ranging from democratic to autocratic
- age ranging from entrepreneurial to established

One side of a triangle represents each of these factors. A line is drawn from each vertex to the point on the opposite side corresponding to the degree to which the organisation displays the particular factor. The triangle formed by the intersection of these lines forms the organisation's style triangle. The concept is illustrated in Figure 6-5 below.

Lee argues that communication is much easier when both organisations have a similar style. Unfortunately young dynamic system integrators have a rather different style from their likely customers which are likely to be long established bureaucracies.

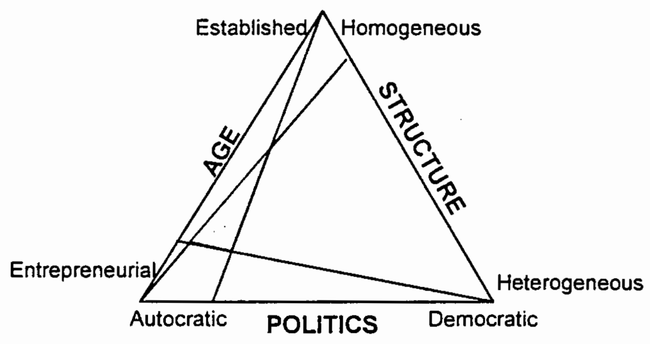


Figure 6-5 The Style Triangle for a Typical Start-up Company

6.4.1 Contract

The relationship between an external consultant and the customer is formalised with a written contract. This should also be done when the consultant is from an internal division. The contract should set out what is required from both parties. This should include the fees to be paid to the consultant, a schedule of payments and the products to be delivered to trigger each payment. In addition the customer might be required to allocate specified personnel to the project team for certain periods.

Unfortunately the contract cannot fully specify what has to be done, because the full extent of the work is not known until after the system analysis and the user requirements study has been completed. For this reason tendering for system development is inherently risky and the behaviour of the consultant will be influenced by his bid. If he finds the actual work is less than he anticipated he will be generous to the customer and may be happy to add extra functions. If his bid was too low he will look for every opportunity to cut costs and to avoid extra work. In system terms, the contract does not absorb sufficient variety in the development system. To remedy this defect, the first task after the contract has been signed is to set up a project team and prepare a project plan. The project plan is described more fully in Chapter 7, but forms a detailed guide to the various system development activities which must be monitored regularly.

6.5 The Development Team

Each of the key groups referred to above must be involved in the system development. Ada Demb (1979, p.15) writes "*Only a team whose expertise addresses the full range of difficulties likely to be encountered throughout an organisation can produce an analysis or plan whose comprehensiveness matches the complexity of the problem*".

It was argued above that system development can only be done on a project basis. However the project team must be correctly assembled and managed. The Project Manager is an important key to the success of the whole project. Demb (1979, p.56) quotes a study by Dickson and Powers at the University of Minnesota which correlated a number of factors believed to be necessary for successful system development with actual outcomes. There was found to be no correlation between the use of a project team and a successful outcome. The result depended on the composition of the team and, in particular, on the manager.

The development team, or project team, forms a system which interacts with the organisation. When the project is undertaken as a so-called 'turnkey' project, the project team is made up entirely of the consultant's staff. Under these circumstances the project is likely to fail through lack of transferability. Because the organisation's staff are not involved in system development other than by completing questionnaires and being interviewed, none of them learn how the system has been designed and how it works - the consultant's technology is not effectively transferred to the organisation.

The answer is to build a project team with members drawn from both organisations. The expertise lies with the consultants, but members of the target organisation with the right education and training who work in the team will acquire an in-depth understanding of the system design process and the system itself. This is the most effective way to begin technology transfer. In the first instance the transfer is only to a small group within the target organisation, but this group is then in a position to spread their knowledge more widely.

It was pointed out above that members of a project team have conflicting loyalties - to the target organisation and to the consulting company. This conflict is handled by designing the team in such a way that all conflict is resolved at one point.

Policy to guide the project must be decided by the respective policy-making systems of the two organisations. This can be handled most conveniently by a steering committee which comprises senior members of the customer and consultant organisations.

The Project Team itself forms a system for the duration of the project.

Figure 6-6 below shows how the elements of a typical project team form a system.

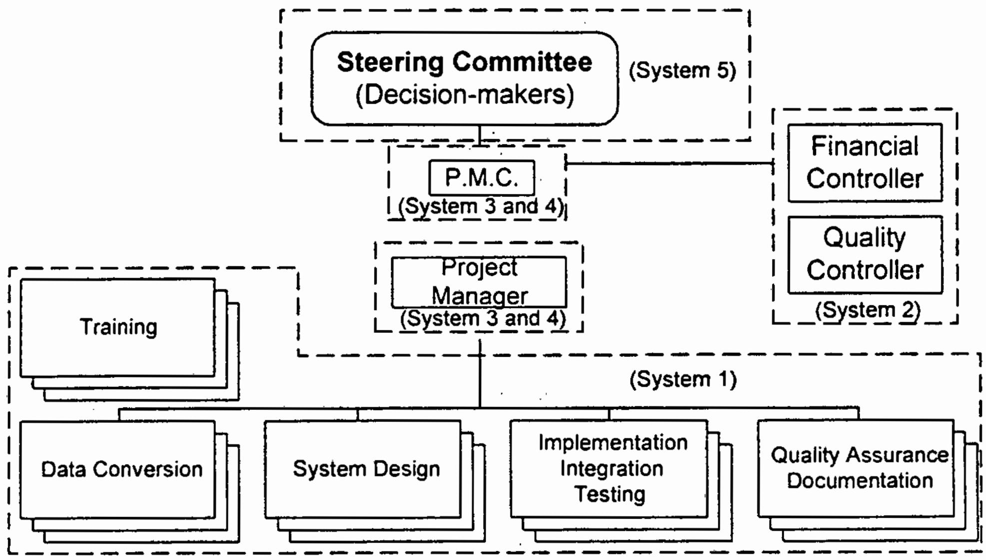


Figure 6-6 Typical Project Team Seen in System Terms

System 1 (Operations) comprises the systems analysts, programmers, operators, trainers, etc. who actually build the information system.

System 2 (Co-ordination) provides co-ordination by enforcing quality assurance measures which should be broadly in line with ISO 9001. The Project Contract and Project Plan form important elements of *System 2*. As the project advances further, so the *System 2* functions become more defined. For example, after the user requirements document has been accepted by the customer, system design work is monitored to ensure compliance with user requirements. Before implementation begins, more standards are introduced such as naming conventions for variables and database tables and fields. By the time the design is completed, the system is fully specified and program coding becomes a relatively low level activity requiring very little management level intervention.

Various *System 2* support systems may be available for financial transactions such as purchases and payments, administration of sub-contracts etc.

System 3 (Monitoring and Control) is represented by the Project Manager. He performs a classic monitoring and control role by comparing progress and costs with the project plan and budget. Depending on the size of the project, he may also have to monitor the technical aspects of the team's work. In large projects assistant project managers might be appointed to deal with areas such as finance, technical standards, training etc.

System 4 (Planning) is the domain of the Project Manager and the Project Management Committee. This committee comprises the Project Manager, the Team Leaders of the various operational groups and representatives from the users groups. They meet regularly to consider changes to users' requirements, the impact of external events such as changes in technology or legislation, and risks to the project, and to plan appropriate responses.

System 5 (The Project Steering Committee) comprises the project decision-makers. In an internal company project, this committee might include the managing director, divisional managers affected by the project, the financial controller and the project manager. When two parties (customer and consultant) are involved, each party's representatives must have the authority to make binding decisions.

To achieve effective system implementation the two systems must work in harmony. Day to day interaction takes place between the Project Manager and the organisation management level. Problems which cannot be solved at this level are referred upwards to the Steering Committee for a final decision. A key factor in a successful project is the authority given to the Project Manager and the backing given to him by senior staff.

Figure 6-7 overleaf illustrates the interaction between the development team and the target organisation.

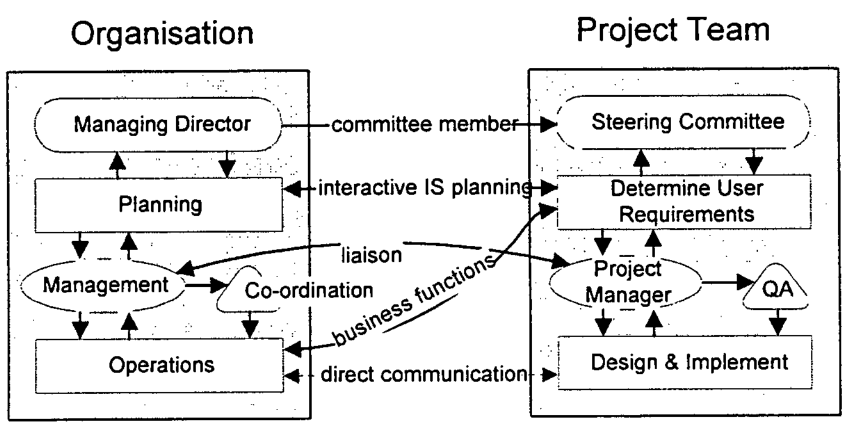


Figure 6-7 The Relationship between the Project Team and the Organisation

In the next chapter the development process will be analysed and the requirements of a project team to carry out the process will be specified.

7. THE DEVELOPMENT PROCESS - PLANNING

Law (1987, p.109) writes "*Nevertheless, like any other project, the development of a system has to be managed. For management to be effective a model of the development process has to be available which provides a sensible framework for the basic management activities of planning, organising, directing, monitoring and controlling work. Obviously, a comprehensive and realistic model of the development process would provide a sound basis for project management across a wide range of variation of the factors mentioned above (*system complexity, technical innovativeness, quality requirements, the constructional components and tools available, the development strategy selected and the human skills available*), but such a model may be too complex for cost-effective use by making control more complicated and planning more difficult (even if more realistic).*" He is emphasising the need to define the project in such a way that the manager controlling the project can understand what is happening and so that the contractual obligations of the parties can be viewed objectively.

7.1 The Development Process

The main business goal of the system development team is to <u>make appropriate use of information technology to enhance the efficacy and efficiency of the organisation</u>. The result is measured by the extent to which this goal is achieved.

Over the years, various sequential models of system development have been proposed. The linear or sequential model breaks the process down into a number of well-defined phases, each of which has a measurable output serving as the input to the next phase. Numerous writers have proposed minor variations on this model, but a number of phases have come to be commonly recognised. These are:

- Problem analysis - the planning phase
  - ⇒ Organisational analysis and review
  - ⇒ Information systems planning
  - ⇒ Project identification
  - ⇒ Project planning
- Requirements Specification

⇒ Analysing the data structures
⇒ Understanding the users' functional requirements
⇒ Defining what the new system should do

- System Design
  ⇒ Designing a system to meet the technical users' requirements
  ⇒ Specifying the hardware, software, and development environment
  ⇒ Designing a user interface to facilitate system use (user-friendliness)
- Technical Specification
  ⇒ Detailed specification of all computer functions
  ⇒ Data dictionary
  ⇒ Database tables, entities, and constraint definition
- Development of Components
  ⇒ Coding of individual computer functions
  ⇒ Testing individual functions
- Integration of Components
  ⇒ Development of global system framework
  ⇒ Integration of components
  ⇒ Testing of entire system
- System Installation and User Acceptance
  ⇒ Installing the system in the operational environment
  ⇒ System testing with realistic test data
- Operational Use and Maintenance
  ⇒ User training
  ⇒ Data conversion/ loading
  ⇒ Switch over to new system
  ⇒ Defect management
  ⇒ System maintenance

These steps do not necessarily follow each other in sequence from beginning to end. There may be iteration within some phases, while other phases can run in parallel. Changes made in later stages may have to be fed back to earlier stages. For example, data conversion should start as early as possible in the project, as soon as the data formats are defined. This ensures that a significant amount of data will be available by the time the project is completed. On the other hand, subsequent changes to the data design will necessitate changes to the data which has already been captured. Successful project managers are aware of this need for flexibility and constantly adapt their plans, no matter what is actually written on their project plan.

At this point the question may be asked "Why, if there is general consensus on the development process, are many systems not successful?" From all that has been written above, the answer is clear - the development methodology is applied mechanistically, as though the organisation is, in Ashby's (1957, p.24) words, a **determinate machine** in the same way as the computer hardware. To achieve success it is necessary to take account of non-mechanistic or Markovian aspects of the organisation - the culture, the interaction of different power groups, the motives and goals of the various groups involved in the development process. These are aspects which do not determine the output of the system precisely but which create varying probabilities of certain outcomes.

7.1.1 Project Management

Good project management does not mean more interference by the manager. As has been shown above, the manager will be overwhelmed by the system variety. Efforts to cope with this variety easily lead to long hours of overtime work detrimental to the project manager's health and personal relationships. Good management means intelligent management. It means putting in place a good co-ordination system (*System 2*) as a filter to reduce the variety reaching the manager, thereby making the development process as far as possible self-regulating. The manager should switch on the auto-pilot to keep the project on course from day to day, devoting his time to planning future project phases and making contingency plans to handle project risks.

Every organisation is unique with unique requirements. It follows that the development system suitable for one environment will not be suitable for an other, hence a rigid development method which proved successful in one case, is unlikely to be successful in other cases.

It was stated above that system development is innovative and best undertaken on a project basis by a project team. At the start the project team comprises a group of individuals. The project manager must turn this group into a work system with operational tasks assigned to some members, control and monitoring tasks to others and planning and policy making assigned to yet others. In addition supporting systems must be put in place to handle administrative and financial functions.

The development process comprises a number of sub-processes broadly corresponding to the phases of the systems life cycle. It is the job of the project manager to ensure that these processes are carried out on time and within budget. His job is not to undertake the development work himself, but to monitor all tasks and take immediate action at the first sign of a problem. A good project manager will spot and correct an incipient problem before anyone else is aware of it, so that his managers (the Steering Committee) just see everything running smoothly. His job is a management job - his team members have the technical expertise needed to do their jobs. He needs 'people' skills to deal firmly, yet without provoking hostility, with the users and members of the development team, and the ability to prioritise the jobs to be done by focusing on the things which are important.

7.1.2 Development Strategies

Various approaches to system development are possible. Law (1987, p.110) lists five strategies. These are:

- one-shot development
- multi-shot development
- incremental development
- evolutionary development
- prototyping

7.1.2.1 One-shot Development

One-shot development means completing all system development before introducing the system to the users with a complete switch over from day one. A good example of this approach is the new Hong Kong Airport where the switch over was followed by several weeks of chaos. This approach is unavoidable for real-time control systems, and also works when the users' requirements are stable over the period of development. However, in the environment in which GIS is used this approach has a number of serious disadvantages:

- The development time for large systems is quite long - perhaps several years. During this period any initial enthusiasm which may have been generated amongst users evaporates. A graphic example is provided by the British Integrated Air Defence System which was eventually completed several years late and many millions of pounds over budget.

- Because the user does not see the system during the development phase, he is not able to visualise all the implications and possibilities of the system until it is delivered, consequently

- it is likely that a large number of changes will be requested soon after system implementation. This may cause friction between the developers and the customer - the developer insisting that he has delivered what the customer asked for, with the customer feeling that he has not got what he wanted.

- The users' requirements are frozen on completion of the user requirements study. This is inevitable because software development becomes almost impossible to manage if new requirements are constantly being given to the developers during the system design and implementation phases. If the development period is extended, by the time the system is delivered the requirements may have changed substantially. For example, the system developed to manage the South Africa cadastre was developed on requirements determined in 1987. By the time the system was delivered in 1994 the requirements had changed to such an extent that they were no longer met by the system.

- People have difficulty in coping with change, and if too many changes are made at the same time, productivity will suffer through the various effects of stress on the work force.

Finally, Law writes (1987, p.128) "*However, developing 'all-singing, all-dancing' systems at one go has become well-known over the years for the regularity with which systems developed in this way have been found to overrun budgets of time and cost by amounts which would have been almost unbelievable if they were not so common.*" The conclusion is that 'one-shot' development is not appropriate for large systems in the commercial or administrative sectors.

7.1.2.2 Multi-shot Development

Law uses the term multi-shot development to mean the development of a system in an unstructured experimental environment by the users, to meet their own operational requirements. Many geographic information systems start in this way, but because of the lack of proper support systems for network management, data security, and data maintenance, the systems either fail or are taken over by professional IT managers. The system initiators and first phase developers often resent 'their' project being taken over by professional IT staff, and the system fails through lack of support by the users.

7.1.2.3 Incremental Development

Incremental development breaks a large project up into a series of sub-projects, each of which produces a useful product within a reasonably short time frame. Each product adds to or improves on the previous stage, and all the products eventually integrate to produce the complete system. Figure 7-1 shows a Gantt chart illustrating the on-going development, installation, and evaluation of sub-systems, with the results of system evaluation being fed back to the development process resulting in revisions to the users' requirements.

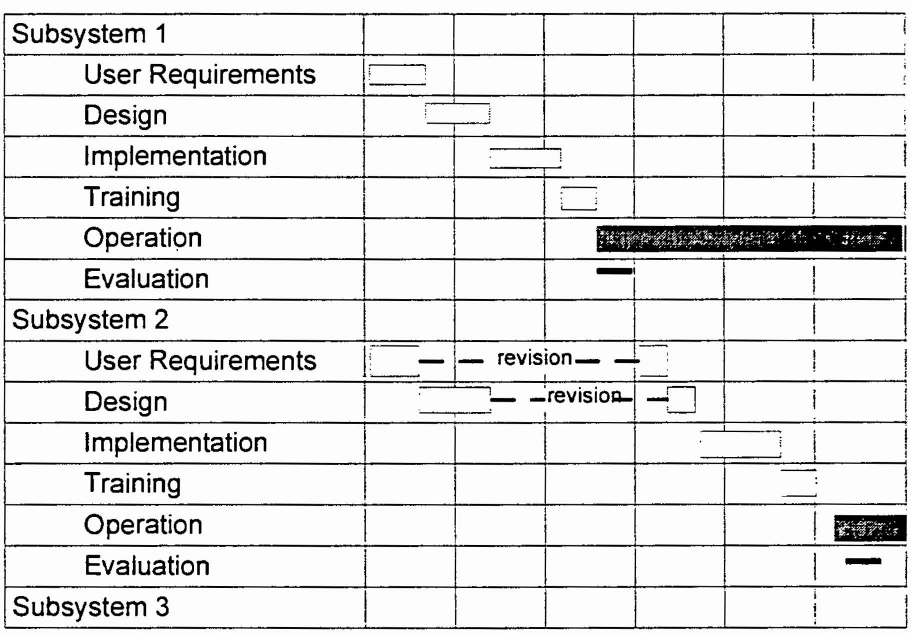


Figure 7-1 Phased Introduction of Sub-Systems with Evaluation

In adopting the incremental development strategy, it is essential to take a top-down approach, working from the whole to the part. It is only in this way that the eventual integration of the sub-projects can be assured.

Law (1987, p.130, quoting Gilb) suggests that the cost of the first sub-project (or pilot project) should be in the region of 1% to 5% of the estimated total cost for the project.

Incremental development brings benefits in three areas:

- Better resource management.
  - Estimating time and cost is easier for smaller sub-projects than for the large scale development.
  - Actual costs incurred in the first sub-projects can be used to improve budgeting for subsequent phases.
- Reduced risk.
  - Initial cost is low and the project can be stopped at any point.
  - Changes requested by users as a result of experience with earlier sub-systems can be incorporated into the system design relatively easily.
  - The effect of mistakes will, in general be limited to the sub-system in which they occur.
- Greater user acceptance.
  - The user gets something useful quickly.
  - Users are involved throughout the development so enthusiasm can be maintained.

7.1.2.4 Evolutionary Development

Evolutionary development is a strategy which is applied to existing systems. In fact most systems begin to evolve from the day they are handed over to the customer. It is common for large systems to undergo almost continuous change.

Problems arise with poorly designed systems when a change to one part of the system has an unexpected effect on another part. It is extremely important that all changes to the system are documented.

There is usually a point at which it is no longer cost-effective to keep on modifying an old system because the hardware is obsolete and because changes to software are causing more problems than they fix. This point is often the starting point for the development of a new system.

7.1.2.5 Prototyping

Prototyping is usually taken to mean the rapid development of a system of limited capability which enables the user to understand specific features of the proposed system more easily. Prototypes are most commonly used in the development of user interfaces. System designers can get feedback from users about proposed interfaces, make changes quickly and repeat the process. This quickly results in an interface acceptable to the user. Special rapid application development tools (RAD) are available. They allow complex windowed user interfaces to be created in days rather than weeks and to be modified in hours rather than days.

7.1.2.6 Strategy for GIS

The advantages of the incremental approach to system development, coupled with the use of prototypes to enable users to give meaningful feedback about user interface design, make this the ideal way to proceed with GIS development. A limited initial phase gives all those affected by the system the opportunity to familiarise themselves with the system concepts, and enables them to provide more meaningful inputs into subsequent development phases.

If Cohen's concept of adaptation or evolution driven by 'contextualism' is correct, then a gradual implementation provides an environment in which adaptation can take place. If 'one-shot' development is used, it may produce a fully developed dinosaur which is unable to survive in the context in which it is placed.

7.1.3 Quality Assurance

Quality Assurance is something which cannot be applied retrospectively to a project. It must be an integral part of the development process. The systems approach to development stresses the control feedback loop in each system. This monitoring and control provides quality assurance. However deciding what output data to monitor and how to monitor it for every process in the development cycle is a substantial task for which a quality assurance support system can be set up.

In order to comply with the international standard (ISO 9002) for software development, the development team are required to produce a Quality Manual stating the principles on which quality is to be assessed and controlled, and a Quality Procedures Manual setting out how each process should be done, what forms or document format should be used, etc.

The Quality Assurance support system has the task of formulating quality procedures and of ensuring that they are actually carried out. This system should be independent of the Project Manager. If a development project is falling behind schedule, a project manager is quite likely to take short-cuts in quality assurance; this can only be prevented by an independent Quality Assurance Officer with sufficient authority. The principle is shown in Figure 7-2.

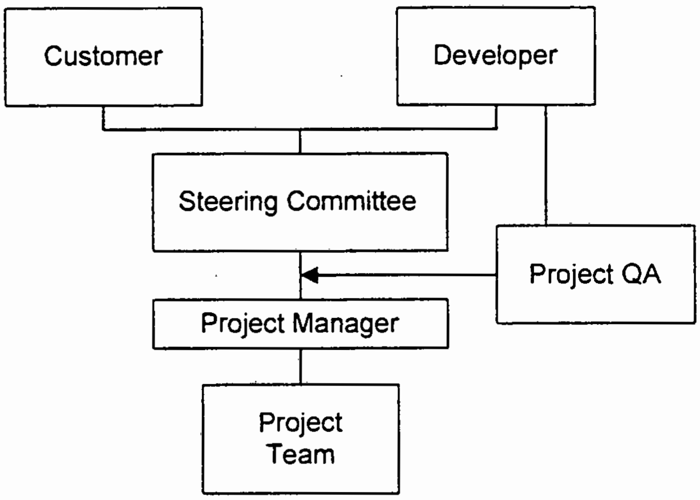


Figure 7-2 Quality Assurance Should be Independent of the Project Manager

Within a development project, the Project QA Officer has the duty of preparing a Quality Assurance Plan which sets out the checks to be carried out on the output of each development task, and who is to do the checking. All checks must be signed off by the Project QA Officer in addition to the team member actually doing the check.

In effect, the QA support system provides a check on the monitoring process in the development system. An analogy might be an engineer checking temperatures and pressures to satisfy himself that his thermostats and regulators are working correctly. The QA support system has a further role in advising project managers how to monitor the quality of their teams' work, and in training everyone involved in system development in the concept of quality assurance.

In many companies there is a strong tendency to reduce quality assurance to a few general statements which sound good but mean very little in practice. In this regard Bronzite (1991, p.157) writes "*Quality Assurance is more important than just a few lines describing some of the possible techniques that can be applied. It is central to reducing the overall costs of system application, but may take a long term investment in time and expertise to make it effective. Much like structured design, quality aspects require the support of top management, the commitment and drive of the project leaders, and the technical inputs from the QA manager or consultant. Quality may cost, but its absence costs more.*"

7.1.4 Development Process Monitoring

A brief reference was made in the Introduction to the question of deciding whether a system is a success or failure. From the systems perspective this entails monitoring the attributes of the system being delivered and comparing them with the specifications. This comparison would normally result in corrections to the development process to bring the actual system more in line with the specifications. However, with the 'one-shot' development strategy there is no second chance - by the time the system is delivered it is too late to use the feedback to modify the system. In this respect too, the incremental approach enables the control feedback loop to be employed more effectively.

The system being developed has a number of attributes which can be measured in various ways. Gilb (1977) suggests a System Attribute Specification in which each attribute of the system is listed together with the measuring concept, the measuring tool, the worst level acceptable, the planned level and best level achievable, and references to relevant documentation.

Primary system attributes include:

- Cost
- Capacity
- Reliability

- Ease of Use
- Delivery Schedule
- Security
- Maintainability

The definition of system attributes and the way in which they will be measured, forms part of the system development quality assurance process. The degree to which these attributes are achieved provides a measure of the development team's success. This is illustrated in Figure 7-3 below.

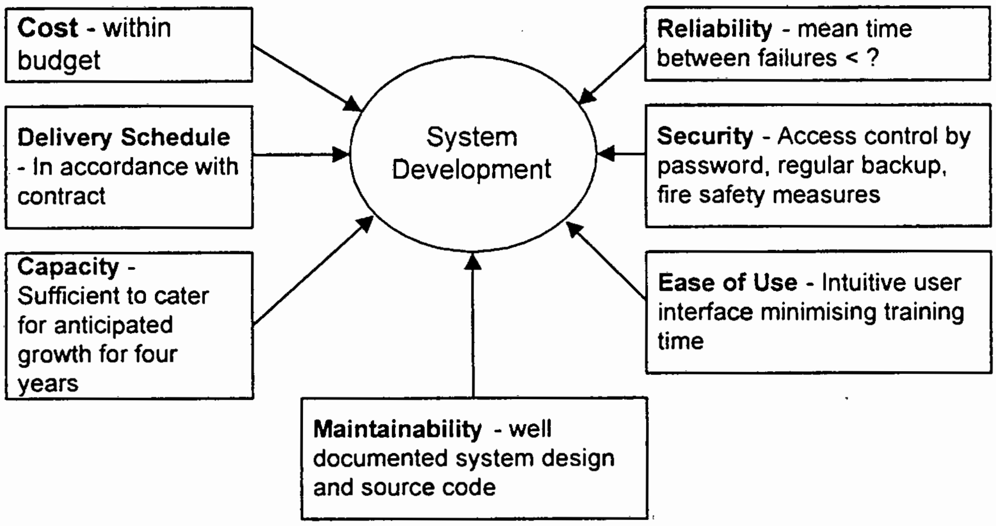


Figure 7-3 Measurable System Attributes

7.1.5 Collecting Information

Information gathering is an important component of system development. In the planning phase broadly-scoped information is needed about the organisation, its goals and business processes, existing computer systems, skills-base etc. In the design phase similar information is needed in depth about specific processes. During the implementation phase the users' reaction to design documents and prototypes is very important.

How can all this data be collected? At the problem analysis stage broad, rather than deep, information is needed. The aim is to obtain an overview of the organisation so that an information systems plan can be prepared and so that processes can be prioritised for computerisation. Later, when the user requirements are documented, greater detail is necessary, but only in relation to the functions which are going to be computerised. That is to say, a broad survey of the organisation is done, followed by a detailed survey of business processes identified for computerisation. This is analogous to mineral prospecting, where a magnetic reconnaissance survey of a large area is followed by detailed seismic surveys of areas which look interesting.

In Kydd's terms, the problem domain at the start of the project is high is *equivocality* and *uncertainty*. Uncertainty can be removed by collecting facts, but unless the equivocality is removed first, time may be wasted on collecting unnecessary facts. Kydd writes (1989, p.281) "*Equivocality resolution requires the sharing of opinions and viewpoints in order to lead to a common interpretation that can direct future activities.*" Equivocality is resolved with *rich* information. This can only be obtained through meetings and dialogues which enable debate and discussion to take place so as to achieve a consensus.

Dialogue is only meaningful when each side understands the other. Hence the consultant must have at least a high-level overview of the organisation, and the management of the organisation must have a broad understanding of information technology. The latter requirement is crucial - decision makers cannot make informed decisions on matters of which they are ignorant. Wessel writes (1979, p.23) "*Experts are useful in conjunction with highly skilled and knowledgeable management, but ... experts may be worse than useless when hired by management ignorant of the field of expertise. ... If management doesn't first understand what it is trying to do, management oughtn't to do it*". Therefore, when information technology is new to management, training should form an important component of the problem analysis phase. Even in cases where management has a good grasp of traditional data processing applications, GIS is sufficiently innovative to require management training in this field.

Rich information is best obtained through group meetings at which the project team can interact with personnel from various levels in the organisation. These meetings should be supplemented by interviews conducted with staff at all levels in the organisation. Senior executives will be interviewed to get information about the goals and business objectives of the organisation. Middle managers, clerks and technicians will be interviewed to gain detailed information about particular tasks or processes.

A lot has been written about interviewing techniques, but a few points should be noted:

- The interviewer should be familiar with the business process and be familiar with the technical jargon used in the field. This assists the interviewer in asking appropriate questions. Systems analysts who don't understand the customer's business are generally ineffective; the customer spends a lot of time explaining what are to him commonplace facts about his business, and resents this waste of time.
- The interview should be recorded. This frees the interviewer from the need to make notes during the interview, and enables him, when reviewing the recording, to pick up remarks and comments which may have seemed irrelevant at the time of the interview.
- The interviewer should be prepared with some key questions. This ensures that the important points are dealt with and that the discussion remains focused. Employees' time is valuable and interviews usually have a time constraint, therefore it is important to remain focused. A checklist containing the main points to be covered and prepared before the interview, provides a useful aide-memoire.

Facts can be acquired conveniently by questionnaire. A well-written questionnaire can elicit a lot of useful information, but it lacks the richness of the interview because further information cannot be extracted through supplementary questions. A questionnaire is more useful in getting hard facts than in measuring opinions and attitudes. These can only be obtained through face-to-face discussions.

Documents used in the business processes provide another important source of facts. These facts may need to be supplemented by interviews to place the documents in their operational context, in other words to answer the questions when and how they are used.

7.2 Problem Analysis - the Planning Phase

Campbell (1995, p.46) writes "*Any information system will only be utilised if it generates information that is of value to users. It is therefore regarded as important that emphasis is placed on identifying the information priorities of the organisation and how such resources should be incorporated into the work of the* *staff. ... They must feel that they have ownership of such a strategy and share in the sentiments that are expressed. In a sense, therefore, it represents the embodiment of the norms, traditions and values of the particular organisation."*

The first step in the project is to prepare an information management strategy or information systems plan by looking at the organisation in its environment, identifying problems and seeing which of these problems can be solved or ameliorated by information technology (IT). This phase of the project is relatively undefined. At this stage it is not yet known which departments should be computerised, what hardware and software is needed, which functions will be carried out by the computer, etc.
The task is to:

- document how the organisation is structured, what it does, and how it functions,
- enquire whether it is doing the right things,
- determine how the organisation could be re-structured to perform its business processes more effectively,
- determine how IT could be used to improve performance,
- prepare an information systems (IS) plan prioritising the introduction of IT into the organisation, and
- define the scope for the first phase of the IS plan, and prepare a project plan for this phase.

The result of this study will be:

- a set of recommendations regarding how the business process can be improved, either without the use of IT, or as a prelude to the introduction of IT,
- a long-term information systems plan or programme for the introduction of IT into every area of the organisation where it can be used cost-effectively, and
- a project plan for implementing the first phase of the IS plan.

This task breaks down naturally into a number of sub-processes which are detailed below. The process is described in Table 7-1 on p.7-28

7.2.1 Organisational Analysis and Review

The first sub-process or business activity to be undertaken is the gathering of information about the organisation. The results of this study form not only a basis for the subsequent tasks of user requirements specification and system design, but also define the development system.

For example, if the organisation is found to be authoritarian in nature with senior management wielding effective power, then the system development will be tailored to this, giving relatively less weight to the views of users and relying on senior management to force acceptance. In an organisation with diffused power and 'hands off' management, the contrary would hold.

Information systems are introduced into existing organisations with established work procedures and established staff hierarchies. Nowadays there are likely to be existing computer systems which must be integrated with the new system. The process of implementing the new system involves changes to the organisation, so that the organisation plus the new information system will be different from the organisation before the changes as illustrated in Figure 7-4.

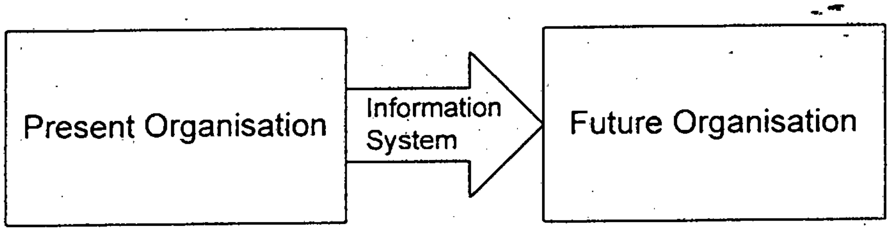


Figure 7-4 Organisational Transformation

Demb (1979, p.15) writes "*In order to manage the consequences of the implementation of a new EDP system, top management must have a clear description of its own organisation. Accurate descriptions of actors, their characteristics and roles, and interactions among actors, their relationships and inter-dependencies, are vital to anticipating the potential impacts of an EDP effort on the organisation*". The first step in system development is to obtain the data from which this information can be extracted.

7.2.1.1 The Functional Hierarchy

Business processes form a hierarchy of tasks. The task performed by an individual worker or agent is found at the lowest level. There is no general agreement on nomenclature so the following terms have been adopted (but not necessarily followed consistently):

Business Objective

The function or role of the organisation as a whole.

Business Process

Business processes may be categorised as either **core** or **support** processes. Support processes include personnel, finance and EDP (electronic data processing) departments which provide a service to the departments performing **core** processes.

In general core processes either receive inputs from outside the organisation, deliver outputs to external customers, or both. These are the activities which directly assist in meeting the business objectives of the organisation. Core processes might include, for example, design, manufacturing and sales.

Business Activity

A business process is built up from a number of business activities. For example the sales process will include marketing, receiving and processing orders, packing and consigning goods, invoicing and collection of payment. Each of these activities will involve a number of distinct steps and will probably involve a number of people.

Task

The task is the lowest level of the hierarchy and represents the function performed by a single operator.

7.2.1.2 The Organisational Hierarchy

Organisations have a hierarchical structure. Every organisation must have a leader or it will break up. The viable system model introduced above, with its recursive decision-making and control units, forms a hierarchical structure. It is almost universal in large businesses for officers to have ranks and to form a hierarchy with each level reporting to the level above. Traditional organisational charts show who reports to whom, but in reality seldom reflect the real structure of authority in the organisation. A number of writers on management have down-played the hierarchical view of the organisation. Beer (quoted in Chapter 2 above) wrote that its only function was to allocate blame when something went wrong. Nevertheless, it does represent, by and large, the pecking order in the organisation and corresponds to differences in income and status. More than a hundred years ago Anthony Trollope wrote "*When men get so high as that, there's no knowing whether they work or whether they don't. There isn't much for them to do as far as I can see. They have to look beautiful, and frighten the young ones.*"(Trollope A., The Last Chronicle of Barset, Wordsworth Editions, 1994, p.286) thereby indicating that filling a high post on the organisational chart does not, of itself, mean a great deal.

When working with the model proposed above, finding out who owns each process, activity or task, who actually does the work, who monitors and controls the process, who seeks ways of improving the efficacy of the process, who makes policies affecting the process, where the resources for the process come from, and who the customers are, is more important than building an organisation chart based on rank.

7.2.1.3 Information Resources

The importance of information has been stressed. To model the organisation it is necessary to discover what information each business process needs, what form this information is stored in, where it is kept and who is responsible for its correctness.

Eilon (1979, p.101) points out that information can be categorised as *perishable*, *semi-perishable*, and *non-perishable*. Information about rapidly changing events is highly perishable. For example, if a man sends a message to a friend to say he is coming to visit him, and the message is delivered after the visit has been made, the information has perished - it is completely useless. Other information such as records of past project costs is relevant for a while in preparing quotations for new jobs, but after that, changes in technology and market conditions render past project costs of little value. This may be regarded as semi-perishable information. Note that the information may be non-perishable for another purpose - an economic historian might find the information relevant to his work at any time in the future.

No information is completely non-perishable (except as material for historical studies) other than religious dogmas which adherents believe to be eternally true. However land forms and basic cultural patterns change so slowly that they may be considered non-perishable for most practical purposes. Maps made a hundred years ago may not reflect current administrative boundaries or land use patterns, but in most cases there will have been very little change in the contours of the land, the river courses, the coast line and the soil types.

Many business activities generate enormous quantities of information which could overwhelm the capacity of data storage equipment if it were all kept, though this is changing with the ability to write a Gigabyte or more of data on to a single compact disc. Data about information resources must therefore include the life span of the data, to enable an archiving system to be incorporated in the information system.

Information can be classified according to the functions to which it relates. For example, information found on maps may be classified as cadastral, topographic, socio-economic, environmental etc. The knowledge of which processes use which information groups is essential for designing databases.

7.2.1.4 Communication Analysis

The system designer must know how information travels between the different business activities. If the organisation is not computerised, the methods are reduced to meetings, telephone discussions, memos, letters, faxes, reports and maps. When the organisation is already computerised to some extent, further options are added such as electronic file transfer, electronic mail, shared access to common data stores etc.

Information relevant to the designer is the network bandwidth (capacity), number of users and topology. When the detailed technical design stage is reached he will need to know the physical network details and data transfer protocols used.

Communication channels carry **messages** i.e. information and other resources between tasks (or the agents performing the tasks). In most traditional methods of analysis, communication is treated as 'data flow' and depicted by data flow diagrams. This is useful for the purpose of understanding the existing work procedures, but does not provide sufficient information from which to identify weaknesses, and on which to plan improvements.

More information can be collected with very little additional effort. Key facts regarding communication include:

Medium

Paper - letter, memo, maps, photographs

Electronic - data files

Transmission mode

Electronic - e-mail, database access

Messenger

Postal service

Content

Acknowledgement required

Does the sender undergo an immediate state transition, or does its state change only when the message is acknowledged by the receiver?

It is often important to know that a message has been received correctly before continuing with further processing. For example, in database applications a 'two-phase commit' is commonly used to ensure database integrity, especially when communications are not completely reliable. The task which is updating the database sends the new information to the database. The database then acknowledges receipt and informs the task that it is ready to process the update. The updating process then sends a simple 'go-ahead' message, and waits for confirmation. In other words the signal to update is only sent once the updating process knows that the data has reached the database safely.

The message containing the actual data may be long and so more likely to suffer from data loss, whereas the actual commit message is very short and is only sent after all the data has been successfully received.

Duration

How long does it take to send the message?

Messages which rely on messengers or postal services may take from days to weeks.

Destination

Which tasks receive the message?

General

Is any action by the receiver triggered?

Is the message necessary?

Could it be sent more efficiently?

Noise

Noise, as a factor hindering communication, was dealt with in Section 3.1.2.5.

7.2.2 The Business Process

The viable system model views the organisation as a recursive set of sub-systems each carrying out business processes. These processes must be identified and a picture of each process built up by answering questions such as:

- What does the process do?
- Is it a core or support process?
- Who does it?
- How long does it take?
- What are the inputs required? Where do they come from?
- What are the constraints?
- What are the outputs? Where do they go to?
- How is the quality measured and monitored?
- Who is responsible for monitoring the process?
- What business activities or tasks make up the process?

7.2.3 Modelling

Once all the information described above has been collected, it may be used to model the business using the system model proposed in Chapter 7.

Each process has an owner or decision-maker (*System 5*). He can stop the process or change the way it is done by introducing improvements.

The process also has a controller (*System 3*) who monitors the process time, costs and quality of output.

There may also be a planner (*System 4*) interacting with the environment to detect changes in customer requirements, and who is aware of new technology which might improve the process. There may not be an individual dedicated to this task, but the function should be carried out by someone.

Finally there is a person or group who actually does the work (*System 1*) and a number of systems to provide guidelines and specifications for the work, secretarial services, accounting services etc.

The input to, and output from, each process forms the content of messages which must be described in terms of source, destination, transmission mode, format etc.

7.2.4 Restructuring the Business

The actual situation can now be compared with the various options produced in the modelling stage. This comparison will reveal what organisational and procedural changes are needed to implement each option. Change in an organisation is always a sensitive issue. If proposed changes are presented in the guise of the information systems plan, as a corollary to introducing a new computer-based information system, management may find the proposals more acceptable. They will, moreover, be aware what changes are culturally and politically possible.

The need for more changes may be revealed during the User Requirements Analysis stage (Chapter 9) when processes are examined in depth.

7.2.5 Information Systems Planning

The Information Systems Plan (ISP) provides guidelines for the development of information technology within an organisation. According to Campbell (p.47) "*The critical issue would seem to be that a robust framework has been established which is widely shared by staff at all levels of the organisation rather than the existence of a highly detailed and lengthy document*". Nevertheless, a written document is easiest way to provide a framework agreed by all and available for reference.

Because of the rapid changes in technology, no ISP will be valid for very long. Thus the plan should be broad rather than deep. Its purpose is to identify the links between departments and processes, shared data, existing computer systems, and to prioritise future development.

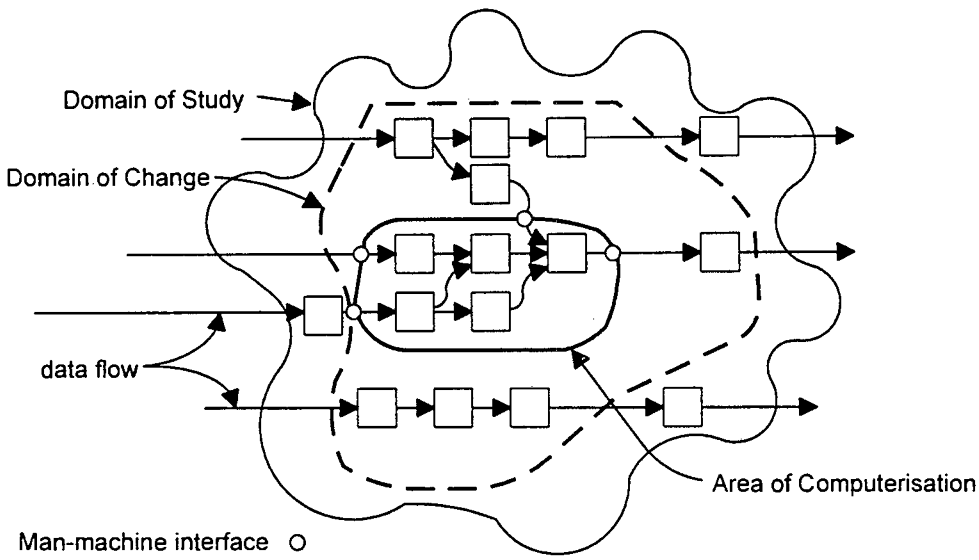


Figure 7-5 Data Flow Diagram showing Domain Definitions

Figure 7-5 above is adapted from Law (1987, p.93). It shows the domains involved in system development.

- The *domain of study* is the broadest area and will may encompass a whole organisation or large division. This area must be sufficiently large to allow all inputs to, and outputs from, the *domain of change* to be fully understood and documented.
- The *domain of change* is the area containing all processes likely to be affected by the introduction of a new system. Hoebeke (1994, pp.33-35) talks of the **adaptive group** of from 200 to 700 people as the largest possible work unit. This would certainly be the largest group to which a computer system could be introduced in one project, and in most cases the group will be substantially smaller.
- Finally, the *domain of computerisation* is the set of processes to be computerised. The boundary of this area defines the man-machine interfaces i.e. the points at which men operate computers.

Project identification involves defining the domain of change i.e. identifying the business or support processes which are causing problems in other processes through delays and poor performance, and defining which processes can realistically be computerised.

Once the domain of change has been identified, the domain of computerisation can be determined. This is a matter of assessing the degree of difficulty and cost of computerising each business task, and the priority to computerise from the point of view of improving the business process.

Many business activities are performed infrequently, for example annual and monthly reports. These activities should enjoy a relatively lower priority in computerisation than daily activities. Some business activities rely on expert knowledge and may not be easy to computerise given the current state of information technology. In other cases, computerisation may be technically feasible, but not economically viable due to high cost of system development or to the fact that the functions are infrequently used.

In some cases a high initial cost can be justified by expected benefits once the system is operational. This tends to be the case with geographic information systems because the cost of hardware, training, and data conversion may all be high, and the system is seldom fully productive until most of the data conversion is completed.

7.2.6 Project Planning

The ISP serves as a guide to the need for computerised application systems and should indicate priorities and approximate scope of each development phase. At the start of a development project there is a great deal of uncertainty and equivocality. The first task when embarking on a development project (perhaps after signing a contract) is to prepare a project plan. In all probability an outline plan would have formed part of the contract negotiations, but it must now be filled out.

The plan attempts to set out, in as much detail as possible, what will be done, when it will be done and who will do it. The plan provides the customer and the consultant with a common framework within which to measure the productivity of the development team.

The main topics covered in the plan are

- project background - what is the organisation's business and why is the project being undertaken?
- description of development process - what tasks will be done?
- description of products - what products will be delivered to the customer?
- project structure - how is the development team structured and who are its members?
- schedule - when will the products be delivered?
- reporting - what reports will be produced and how frequently, what meetings will be held and who will take part?
- documentation - what documents will be produced for delivery to the customer e.g. user manual, technical manual? Documentation is often seen as a time-wasting chore by developers, and as a waste of money by clients. However some documentation is essential for the system to be maintained, enhanced and linked to other systems. Complete documentation of the users' requirements also provides written evidence of what was agreed between developer and client, and can prevent subsequent disputes.
- quality assurance - what QA procedures will be applied to each process and product e.g. document review by committee, code walk-through, and when will each activity take place? Quality assurance also includes standard procedures for writing and annotating computer code, naming variables, database tables and entities etc.
- training - what training will be given to each level in the customer organisation - users, technical managers, and higher management?
- testing - how will the system be tested, and what criteria will be used to assess whether the system complies with the user requirements document?
- risk management - what are the potential threats to the success of the project and what counter-measures are available?

Some of these items such as training, quality assurance and system testing may be expanded into complete sub-plans.

The plan must be agreed and approved by the customer and the consultant.

Although agreed, the plan should not be rigid. The project manager will need to modify it from time to time to take account of changing requirements and unforeseen circumstances.

The plan is the major *System 2* component of the project. Every member of the team can see from consulting the plan what they should be doing and when they should be doing it. Progress is monitored through regular project meetings at which all the participants report on progress, problems, delays etc. Using this information, the project manager is able to take corrective action to keep the project on course.

7.3 Process Analysis

Figure 7-6 below shows the first-level breakdown of the problem analysis phase; Figure 7-7 overleaf illustrates the development system. This phase leads to a detailed project plan for the development of the first phase of system implementation. In tables 7-6 and 7-7 below these processes are analysed according to the model proposed earlier.

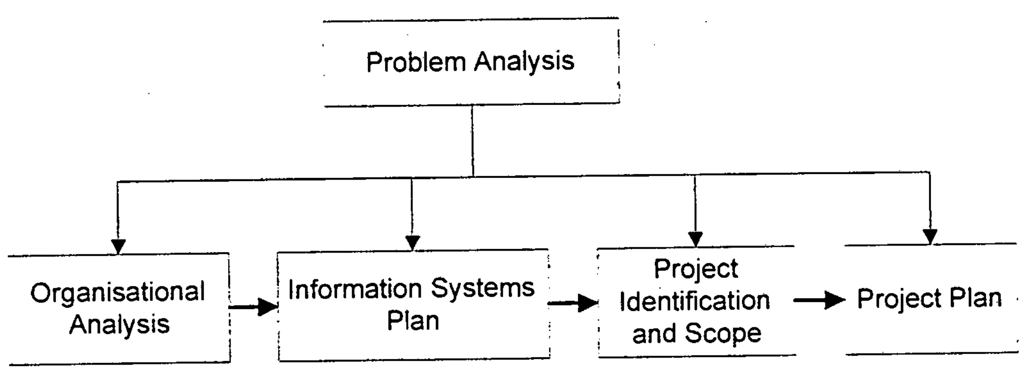


Figure 7-6 The Problem Analysis Phase

During this initial phase the development system is *soft* in Checkland's sense, or, in Kydd's terms, high in *equivocality*. Success depends primarily on good communication skills to obtain all relevant information, and to explore the various possible options with the users. The users actually form a part of the development system providing a second feedback loop as shown in Figure 7-8 overleaf.

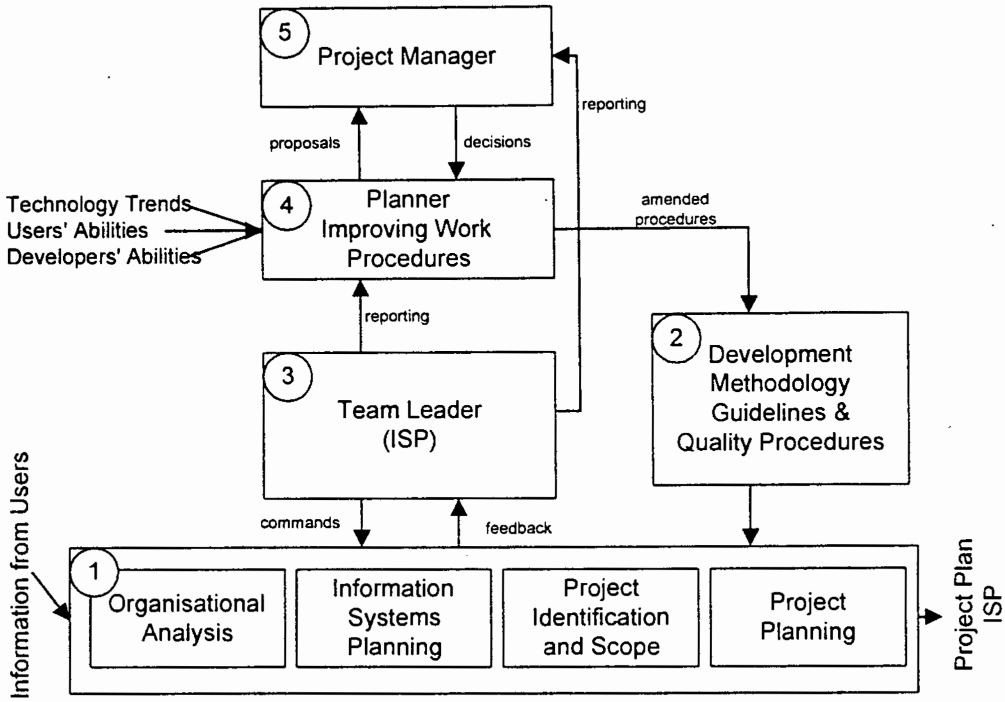


Figure 7-7 The Development System for Problem Analysis

The support systems (*System 2*) provide the environment for both these monitoring activities. The style, format, topics addressed, etc. are prescribed in the system development methodology (e.g. Process Engineering) and compliance is monitored by the process controller (Project Manager). *System 2* also provides guidelines on how reviews with users should be conducted, though in this area is there is naturally much greater flexibility.

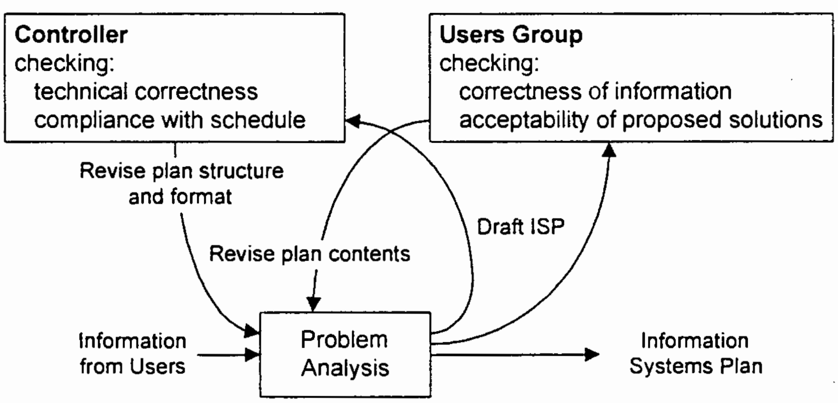


Figure 7-8 Double Feedback Loop in Problem Analysis Phase

The problem analysis is undertaken partly in parallel and partly sequentially. For example, a system analyst may be assigned to study each business unit. These will work in parallel, each with a specific business process to study. A number of sections of the ISP will be drafted. The drafts will be given to the business unit for review, and the resultant feedback will be incorporated into the draft. This all happens in parallel; the various sections are then integrated into the ISP document and the whole plan is reviewed and revised - this is a sequential process.

Process	Problem analysis
Process Description	An organisational study producing (perhaps) recommendations for change, an information systems plan and a project definition.
Owner	Chief Executive Officer - process must be initiated at highest level.
Owner Qualities	An open mind towards the consultant's recommendations and preparedness to dedicate the necessary time to discussions.
Actor	Management Consultant.
Actor Qualities	Good communicator, must be able to draw out the necessary information from employees at all levels in the organisation. Important also to understand the business and the cultural environment.
Controller	Senior Management Consultant or Project Manager/Users.
Monitoring Process	An internal review by senior consultant(s) ensures the logic and consistency of the analysis and recommendations and checks the format and style of the ISP for compliance with methodology guidelines. Users review the plan to check that it is in line with their corporate vision, that it is feasible in terms of technical and financial capabilities and that the contents are factually correct. By developing the ISP in close collaboration with the users/ customer management, the formal acceptance of the plan is assured.
Client	User organisation management (Client and Owner are the same).
Client Characteristics	Variable - generally looking for value for money. Will have good knowledge of business processes, but knowledge of information systems may vary from extensive to nil.
Pre-Conditions	Support of user-organisation management, management must have a broad understanding of information systems.
Input	Information about the organisation - its business processes, information resources and existing computer and communications facilities.
Output	Information systems plan, recommendations for organisational change, project plan for system development phase I.
Post-Conditions	An information systems plan is available, the domains of change and computerisation have been defined and plans have been prepared to develop the first information system required under the IS plan.

Table 7-1 Process for Problem Analysis

Process	**Organisational analysis and review**
Process Description	An organisational study producing (perhaps) recommendations for change.
Owner	Chief Executive Officer.
Owner Qualities	An open mind towards the consultant's recommendations and preparedness to dedicate the necessary time to discussions
Actor	Management Consultant.
Actor Qualities	Good communicator, must be able to draw out the necessary information from employees at all levels in the organisation. Important also to understand the business and the cultural environment.
Controller	Senior Management Consultant.
Monitoring Process	Monitored by reviewing documents to check that all necessary data has been obtained and that meetings have been held with all relevant users. Progress reports and minutes of customer review meetings are studied.
Client	User organisation management (Client and Owner are the same).
Client Characteristics	
Pre-Conditions	Support of user-organisation management. Management must have a broad understanding of information systems.
Input	Information about the organisation - its business processes, information resources and existing computer and communications facilities.
Output	Report on organisational structure and business process structure together with recommendations for organisational change.
Post-Conditions	An agreed view of the organisation including mission statement, clearly defined goals, core business processes and support processes.

Table 7-2 Sub-process for Organisational Analysis and Review

Process	**Information Systems Planning**
Process Description	An analysis of existing computerisation and business processes leading to a plan for the future development of information technology within the organisation.
Owner	Chief Executive Officer.
Owner Qualities	An understanding of the issues raised in discussions about the information systems plan.
Actor	Information Technology Consultant.
Actor Qualities	Well informed about technology, with an analytic and logical mind able to produce a plan from the mass of data collected.
Controller	Senior consultant.
Monitoring Process	Monitored by reviewing draft copies of ISP to check format and style and feasibility of contents
Client	User organisation management (Client and Owner are the same).
Client Characteristics	Variable - generally looking for value for money. Will have good knowledge of business processes, but knowledge of information systems may vary from extensive to nil.
Pre-Conditions	Support of user-organisation management, management must have a broad understanding of information systems.
Input	Information about the organisation - its business processes, information resources and existing computer and communications facilities.
Output	Information systems plan, recommendations for organisational change, project plan for system development phase I.
Post-Conditions	An information systems plan providing a guide to the development of information systems in the organisation over the next three to five years. The plan covers the integration or scrapping of existing systems, general training needs and priorities for system development.

Table 7-3 Sub-process for Information Systems Planning

Process	**Project Identification and Scope**
Process Description	A system is identified from the ISP for immediate development. The scope of the project is defined. Note that this need not be the system with highest priority in the ISP e.g. the system most badly needed requires release X of software Y which is not expected for another year. In the meanwhile a system with lower priority can be developed.
Owner	Chief Executive Officer.
Owner Qualities	An open mind towards the consultant's recommendations and prepared to dedicate the necessary time to discussions.
Actor	IT Consultant.
Actor Qualities	An ability to weigh up the costs and benefits, both financial and social, of each possible system and the ability to make and defend a recommendation.
Controller	Senior consultant.
Monitoring Process	Feedback from users on the implications of various proposals.
Client	User organisation management (Client and Owner are the same).
Client Characteristics	Good knowledge of business and users needs and priorities.
Pre-Conditions	Application systems required by the users have been identified and prioritised in the ISP.
Input	Information Systems Plan, available résources.
Output	Project definition and scope for each implementation phase.
Post-Conditions	A development project has been identified.

Table 7-4 Sub-process for Project Identification and Scope

Process	Project Planning
Process Description	Preparation of a detailed plan for the development and installation of the (sub)-system identified as the highest priority in the Information Systems Plan.
Owner	Chief Executive Officer.
Owner Qualities	An understanding of the development process and the ability to evaluate the plan from a management perspective.
Actor	Project manager.
Actor Qualities	A good understanding of the business and information technology, the ability to related to the customer management and users and to build rapport with them, an ability to manage the project team effectively by providing leadership and the ability to identify potential problems and plan counter actions before the problems occur.
Controller	Project Management Committee - Project Manager and those responsible for providing resources (supplies and services).
Monitoring Process	Review by PMC and customer management.
Client	User organisation management (Client and Owner are the same).
Client Characteristics	Has good knowledge of business processes, but knowledge of information systems may vary from extensive to nil.
Pre-Conditions	All users who will be involved in the development process must have sufficient training to enable them to play an effective role.
Input	Information from the Information Systems Plan about the business process, development priorities, existing computer systems, available skills. Availability of resources including manpower, work areas, hardware and software.
Output	Detailed project plan covering products to be delivered, delivery schedule, training program, quality assurance measures, test procedures, procedures for handling change requests and defect management.
Post-Conditions	A plan which, when implemented, will result in the delivery of an effective operational information system.

Table 7-5 Sub-process for Project Planning

8. THE DEVELOPMENT PROCESS - SYSTEM DESIGN

The planning phase of the work produces a high-level Information Systems Plan (ISP) from which a development project is identified, and a project plan prepared to control the development. The next phase of the work is the design of a real system i.e. a system which can be implemented and operated within the constraints of budget, skills and technology, to meet the goals of the ISP.

The system design phase comprises three stages, each of which is considered below. These are:

- Specifying the Users' Requirements
- Designing the System
- Preparing the Technical Specifications

8.1 Requirements Specification

The requirements of the proposed system are sketched very broadly in the Information System Plan. The first step towards designing an operational system is to identify the requirements in detail. This means identifying the business processes which fall within the scope of the project, and breaking these down to the tasks performed by individual workers. The analysis of the processes includes an analysis of the structure and flow of the data handled by the processes.

It must be remembered that not all tasks can be readily computerised in an efficient and cost-effective manner. Users must be made aware of the implications in terms of additional cost or delay to the project for the functions they would like.

8.1.1 The Development Process - Users' Requirements Specification

Figure 8-1 overleaf and Table 8-1 on p.8-4 show the system for preparing the Users' Requirements Specification. The different parts of the system each have a specific role to play in order to ensure a successful outcome. The component numbers follow Beer (see p.2-20).

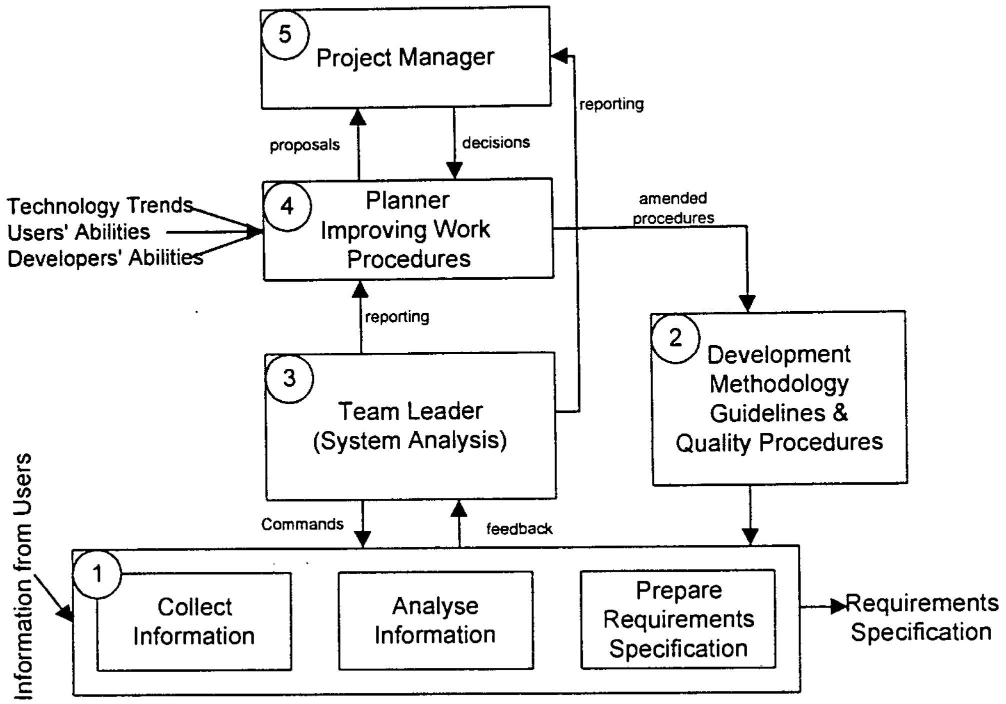


Figure 8-1 Determining the Users' Requirements

- *System 1* - Operations

  The process breaks down into three main sub-tasks -

  ⇒ collecting information

  ⇒ analysing the information

  ⇒ writing the User Requirements Document

- *System 2* - Co-ordination

  The development methodology guidelines and quality procedures manual should provide fairly detailed instructions on how to carry out the work. This is important because it ensures that every analyst working on the project does their work in a consistent manner. The final document may be the work of many, but it should look as though it had a single author. Later, the technical specifications become much easier to write if all the users' requirements are set out in the same way.

  The Project Plan is also an important component defining the project scope and development schedule.

- *System 3* - Monitoring and Control

  The leader of the team formulating the users' requirements has the duty of monitoring the work his team is doing. This involves checking the data collection - are the right data collection methods being used? Are the correct people being seen? Has the information given been verified by another informant?

  The analysis of the information must also be checked by examining data flow diagrams for logical consistency, and by verifying the analysis with the users.

  The actual User Requirements Document must be checked for correctness of content by reviewing it with the users. In most cases the users are not familiar with data processing jargon and may not understand the document. For this reason it is important to spend as much time on the review as is necessary to ensure that it is correct, that everything is explained carefully to the users and that they understand it.

  The document must also be checked for presentation - spelling, layout, consistency in format, binding etc. Good presentation has a significant psychological effect on the users. It creates a feeling of confidence in the development team.

- *System 4* - Planning

  The planning function is often overlooked, but is nevertheless important. The planner should be aware of the capabilities of users and developers, of trends in technology and of the organisational ethos. From this perspective he should review the methods being used to see if they are leading to the desired result, and if not, to propose changes to the project manager. In an actual development team, the planning role might be filled by the project manager, or by a team leader, but it must not be overlooked because it makes the difference between the mechanical application of a method and the adaptation of the methodology to the circumstances of the particular case.

- *System 5* - Executive

  The project manager serves as the decision maker for all matters affecting the way the work is carried out. Ultimately he is responsible for the success or failure of the project and must authorise any deviations from the agreed project plan.

8.1.2 Collecting Information

Collecting information about business processes was dealt with in Section 8-3. At first sight it might appear that the collection of data to specify detailed users' requirements, would be high in *uncertainty*, but relatively low in *equivocality*. In other words, a lot of hard facts are needed with relatively little open to discussion. It is true that a lot a facts are needed - what forms are used for an application, what data fields are on the form, who deals with the application, how is the application processed, etc. By collecting these facts a detailed picture can be built up of exactly how the process is carried out, either manually or with an existing computer system.

Process	**Requirements Specification**
Process Description	Preparation of a document describing the data elements and functions which are to be computerised
Owner	Project Manager
Owner Qualities	An understanding of the development process and the ability to evaluate the plan from a management perspective
Actor	System Analyst
Actor Qualities	A good understanding of the business and information technology, the ability to relate to the users and to build rapport with them. An analytical mind to classify and arrange all the information collected.
Controller	System Analysis Team Leader
Monitoring Process	Technical Review/ User Review
Client	User organisation management
Client Characteristics	Has good knowledge of business processes, but knowledge of information systems may vary from extensive to nil.
Pre-Conditions	All users who will be involved in the development process must have sufficient training to enable them to play an effective role.
Input	Information from the Information Systems Plan about the business process and existing computer systems. Additional detailed information must be collected.
Output	User Requirements Specification document describing functional requirements and data elements in a system-independent fashion.
Post-Conditions	A set of requirements which can be used to design a system

Table 8-1 Requirements Specification

However, consistent with not wanting to 'automate the mistakes of the past', it is necessary to see whether the process can be improved. Are all the items of data on the application form really needed? Is every task in the process justified? etc. These issues can only be resolved through detailed discussion with the users and their managers. It often comes to light in such discussions that no one actually knows all the steps making up a particular process - each operator knows only his task, the manager knows what happens in his unit, but not what happened before the work came to his unit or what happens to it after it leaves his unit. The next manager up in the hierarchy knows that the process is being done, but has no detailed knowledge of how it is done.

One of the principles of 'business process re-engineering', implicit in the viable system model, is that every process should have an owner. It is clear that every process does have an owner if one goes high enough up the hierarchy, but this level may be so high that from there the detail of the process cannot be seen. This changes when the computer system includes automatic event monitoring which is able to trigger warnings at any level when processes are delayed. Event monitoring though, is a very sensitive issue with staff who may get the feeling that the boss is looking over their shoulders.

The inclusion of such matters in the Requirements Specification is high in *equivocality* and requires lengthy discussions with all affected parties.

At this stage, when information has been gathered from all the parties involved, the users' requirements can be prioritised. There are the fundamental requirements, and other requirements which would be 'nice to have', but are not essential. The users must balance the usefulness of these additional features against the increased cost and time required. Sometimes, where the additional cost is minimal, the developer may include some additional features as a gesture of good-will.

8.1.3 Data Analysis -Analysing the Data Structures

Every process uses data which it transforms to create new or modified data. For example, in making a decision on an application to sub-divide a parcel of land, the planner would need to know the size of the land, the size of the sub-divided portions, the present use of the land, the proposed use, the present and proposed access routes, zoning according to the master plan, provision for services and many other items of information.

In order to store this mass of information in a computer system it must be categorised and organised in such a way that it can be readily retrieved when needed. Many ways of analysing and structuring data have been proposed and used, but in practice these turn out to be variants of either the entity-relationship or the object-oriented model. There is even a good deal of correspondence between these models - an entity corresponds to a class of object, while a record corresponds to an object. Object attributes and record fields correspond. The most significant difference between the models is in the treatment of relationships. In fact, even when an object-oriented model is used, it generally has to be mapped on to a relational table because object-oriented databases are not yet mainstream products. They are not yet known to be stable and to have a good data retrieval performance when the volume of data is large and there are a substantial number of users.

8.1.3.1 Entity-Relationship Analysis

The entity-relationship model proposed by Chen in 1976 is central to the use of RDBMS, and is a standard tool for system developers. The model is covered extensively in every textbook on database design. A simple example will suffice to illustrate the basic concept.

An entity type is a class of similar objects such as land parcels, development applications or applicants. Each entity may have attributes which describe it in more detail, for instance a land parcel has an area, a land use, an owner, an occupier, a location etc. An important characteristic of an entity is that is must have a unique identifier which may be an attribute or combination of attributes. For example a land parcel must be uniquely identified, perhaps by a registration district and parcel number.

Entities are connected by relationships, for example a development application is made in respect of a land parcel. Relationships may be many-to-many, one-to-many, or one-to-one. The relationship between a land parcel and a development application might be any of these, depending on the regulations governing such applications.

The entity-relationship model is usually shown in a diagram such as Figure 8-2 overleaf.

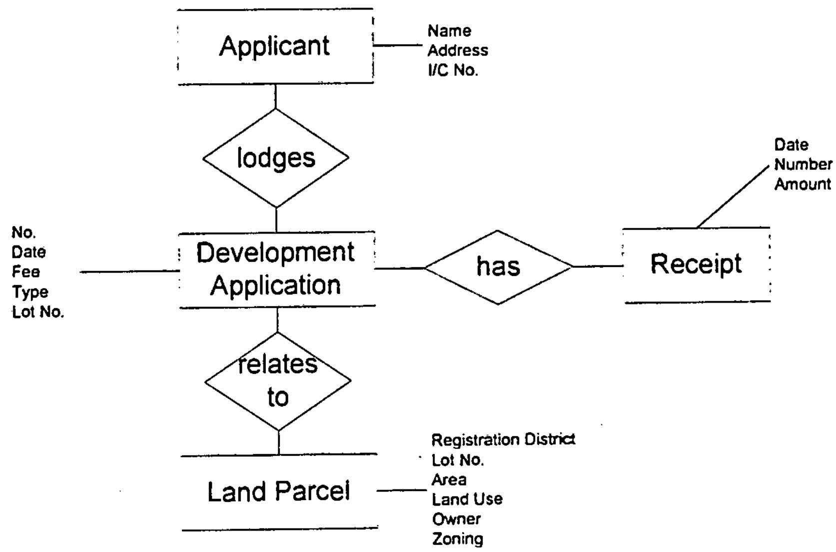


Figure 8-2 An Entity-Relationship Diagram

8.1.3.2 Data Flow Analysis

Data cannot be seen purely as a static resource. It is dynamic, it moves between tasks and data stores, being transformed at some points. The dataflow diagram is used to capture the dynamic nature of data. It depicts the flow of data between processes, the processes, the person or department responsible etc. Figure 8-3 overleaf shows a simple example. The data flow diagram (DFD) can be built up in a hierarchical fashion, with supplementary pages showing the detail within high-level processes.

The data flow diagram has three main functions in the system design - it shows where each system function takes place, and what data is needed for the function; it serves as a template for the workflow management system; and it highlights areas which could benefit from computerisation e.g. if one application produces a printed report which is sent to another department where the data is keyed into the computer again, this fact can be clearly seen from the DFD.

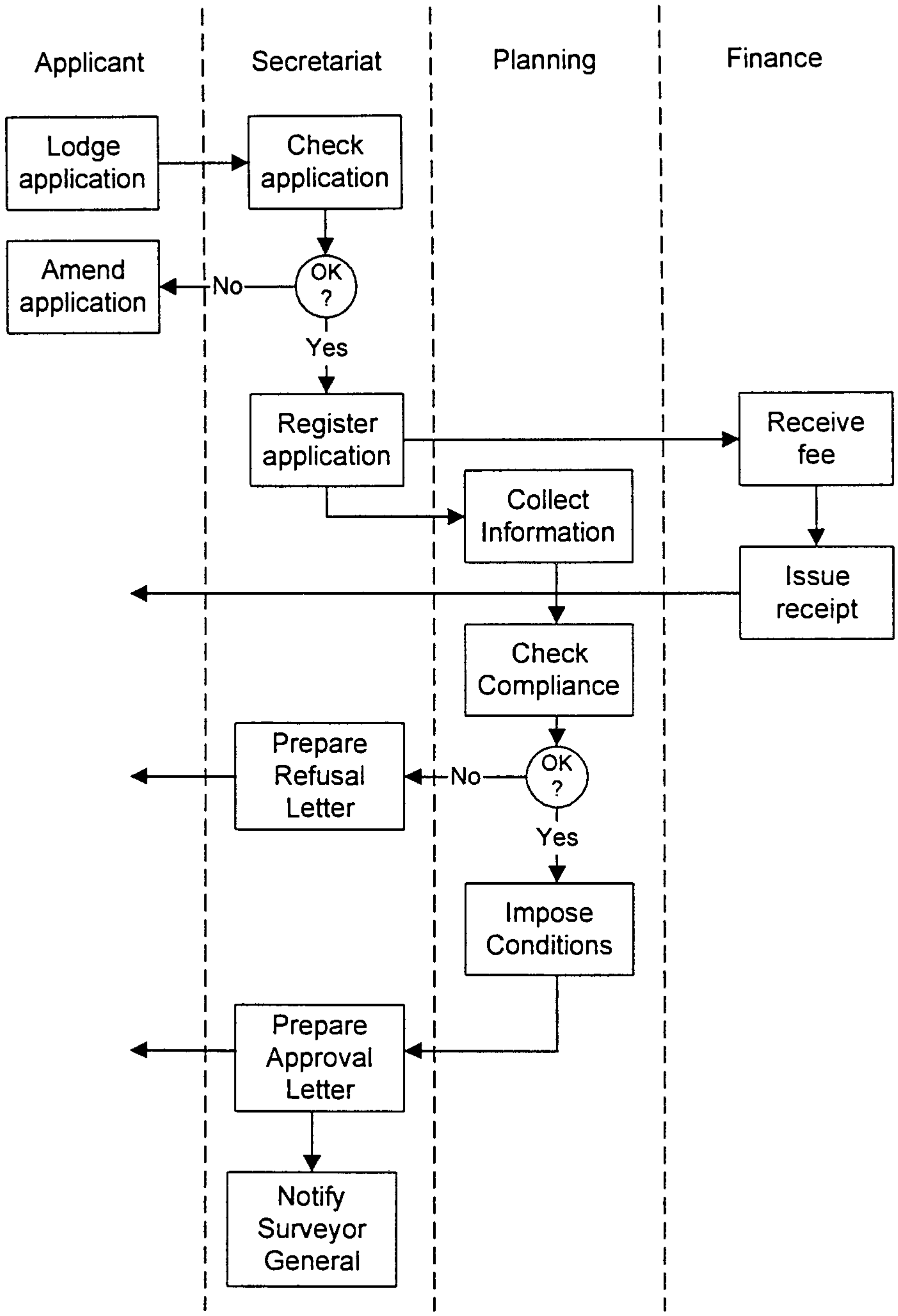


Figure 8-3 A Data Flow Diagram

8.1.3.3 Object-Oriented Data Modelling

The object-oriented model has been the object of research for some years, and is now well-established in all the principal programming languages such C++, Ada, Objective Pascal, etc. However it has not been widely adopted yet for data modelling. One of the problems has been whose model to use - a number of researchers have published books, each using different terms and notation. This issue has finally been resolved with the adoption of the Unified Modelling Language (UML) as the industry standard for object-oriented modelling. The standard covers the whole design process from the business process right down to the functional specification. Now that standards are in place it is expected that the 'OO' approach to design will become much more widespread.

8.1.3.4 Map Analysis

Maps are the basis of non-computerised geographic information systems. Maps all have one feature in common - they show the position of the features shown on the map, either relative to each other, or relative to an external frame of reference.

Maps may contain information about a wide range of features e.g. property boundaries, coastline, vegetation, contours and slope, roads, soil types etc. Graphic symbolism is used to identify the different features. These include colour, line thickness and style, symbols, and text fonts and styles. For example, when the user sees, a yellow line 2mm thick on the map, he knows it is a major road because this is indicated on the legend in the map border.

Points to consider when analysing a map include:

- What information is available on the map?
- What is the source for each data set? Agency and method of data collection?
- Who produced the map?
- Is the map authoritative for any data set?
- Scale?
- Accuracy - is numeric data available?

The information sets relevant to the application must be identified, for example a planning application may group all electricity distribution cables together in a single category, while an electrical facility management system would create a number of different categories based on voltage, cable type etc.

The particular GIS software selected may affect the classification of data. For example, Arc/Info does not allow point and polygon features to be mixed in a single "coverage", similarly power lines cannot be mixed with land parcels because wherever the power lines crossed a property boundary, a new sub-division would be created.

8.1.4 Understanding the Users' Functional Requirements

Each business process is broken down to discover how the process is done; what the various steps are which make up the process; what inputs are needed for each step, and what outputs are produced. This 'reduction' may appear to be in opposition to the systems approach of looking at the whole, but it is not, provided that it is remembered that a single component may not behave normally when isolated from the system. For example, an individual user may agree with the concept of task monitoring when he is alone with the system analyst, but when he returns to his colleagues he is likely to follow the group attitude. It may be more important to a worker to get on well with his co-workers than to strive for greater efficiency at work.

Each step is examined to see if it is feasible to computerise it or not. For example, it may be technically feasible to check building plans automatically for compliance with the building regulations, but the programming effort needed to achieve this may not justify the cost. Automatic checking of building plans also implies that the plans are submitted in an electronic format which is compatible with the checking program. It might be possible to achieve this when working with an internal architecture department, but to expect to get suitable submissions from a wide range of private architects might not be realistic.

For each function which is to be computerised, a specification should be written down giving at least the following information :

- Description - what the process does and who does it
- Input - what data is used in the process and where it comes from
- Output - what is produced by the process and where it goes
- Pre-conditions - are there any conditions which must be fulfilled before this function can be performed?
- Post-conditions -
- Constraints - is input data constrained to a particular range? Should the process be aborted if the output values are outside a particular range? Can the process only be executed at a certain time or by a particular person, or group of people?

8.1.5 The Requirements Specification

The Users' Requirement Specification is a key document in the system development process. It defines what the customer expects the new system to do. It is essential that it be accepted and approved by customer and developer. Later in the development process, it provides a point of reference for user acceptance testing.

The Requirements Specification covers the users' functions and the data structure referred to above.

Approval of the requirements specification is problematic. The customer manager and users who have to approve the specification probably do not understand the technical description of the functions and data, and cannot visualise how the system will look and behave. It is the responsibility of the developers to ensure that the customer not only agrees with what is being proposed, but thoroughly understands it. The onus is on the developer to take the lead in the discussions and to satisfy himself that the users agree and understand.

It is important to allow sufficient time to go through the document page by page, with full discussion of each page. This may result in a series of amendments to the specifications which should then be reviewed again. The main issue is that the customer understands what he is agreeing to. It is relatively easy for an experienced system analyst to persuade the customer to accept a requirements specification, but, if the customer does not understand what he is getting, he will be unhappy when the final system is installed and say "But I didn't think it would be like this!" For this reason an iterative approach using prototypes where possible, is advocated. This gives the customer a better idea of what to expect than does a volume of technical writing.

8.2 Logical System Design

The Logical System Design is a high-level conceptual design which is independent of any particular proprietary hardware or software products. It includes the arrangement of workstations and server(s), network, peripherals, user interface and the data schema. In cases where purchase by public tender is obligatory, the logical system design forms a basis for the tender specification.

8.2.1 The Development Process - Logical System Design

Figure 8-4 overleaf shows the system for preparing the System Design. The different parts of the system each have a specific role to play in order to ensure a successful outcome. The component numbers follow Beer (see p.2-20).

- *System 1* - Operations

  The process breaks down into three main sub-tasks -

  ⇒ defining the logical structure of the system

  ⇒ specifying hardware, software and development environment

  ⇒ defining user interface

- *System 2* - Co-ordination

  The logical system design is an expert task, and for this reason cannot be easily reduced to a set of prescriptions. There may be certain corporate guidelines to follow such as network protocol, or even brand of hardware to use, but in general the designer has a fairly free hand to produce a system which will meet the users' needs.

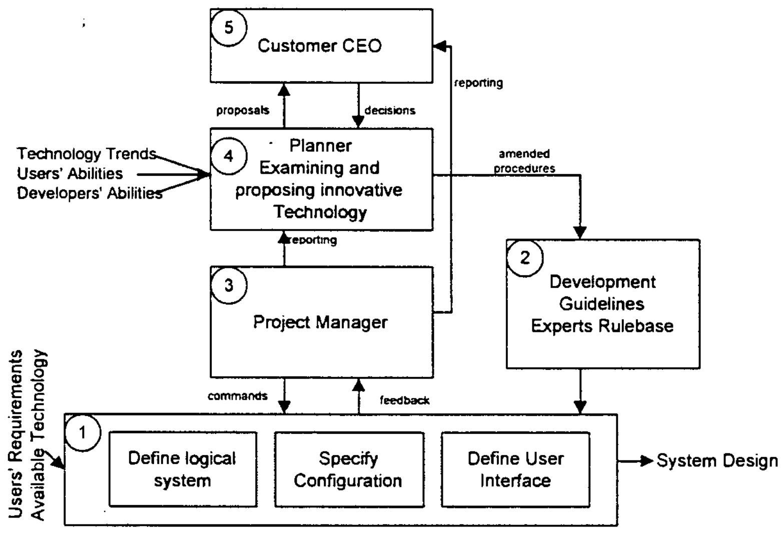


Figure 8-4 Designing the System

- *System 3* - Monitoring and Control

  The system design is monitored by the Project Management Committee. This committee generally includes specialists in hardware, networking, system and application software. The individual specialists check the design for feasibility, efficiency and cost effectiveness. In the light of the feedback from the committee the design is refined.

- *System 4* - Planning

  Innovation in system design must be tempered with realism. Innovative products or ways of handling data may be very successful, but may be disastrous to the system if they do not work. Success is far more likely when using a tried and tested design because the technical side will work even if there are problems on the organisational side. Another point to remember is that the customer may not be able to handle an unfamiliar product. For example if the design is built around an object-oriented database, while the users are only familiar with relational databases, a significant risk factor is introduced to the project.

- *System 5* - Executive

  The system design requires high-level approval from the customer i.e. from the CEO or a senior manager, who may not be technically qualified to make a decision. In practice the CEO relies on his technical managers' opinion. In cases of internal system development the decision is made on the advice of the project manager who is then endorsing his own recommendation.

Table 8-2 overleaf describes the design system and its components.

Process	System design
Process Description	Design of a suitable system to meet the users' requirements. Specific hardware and software products are not considered at this stage.
Owner	Customer CEO or senior manager
Owner Qualities	An understanding of the development process and the ability to evaluate the design from a management perspective
Actor	System analyst
Actor Qualities	An ability to design an efficient system to meet users' current requirements, with the ability to expand to keep pace with future needs. Experience and familiarity with the latest trends are important.
Controller	Project Manager/PMC
Monitoring Process	Review of design by suitably qualified experts
Client	User organisation management.
Client Characteristics	Has good knowledge of business processes, but knowledge of information systems may vary from extensive to nil.
Pre-Conditions	A comprehensive User Requirements Document including a data dictionary and sizing information.
Input	Information from the User Requirements Document.
Output	Logical system design showing distribution of functions between client and server, distribution of data, security structure, network configuration.
Post-Conditions	A logical system design which can be realised by specifying the necessary hardware and software in terms of what is actually available in the market.

Table 8-2 System Design

8.2.2 Designing a System to Meet the Users' Requirements

In designing the system there are several major constraints to be considered. These are:

- **Cost**

  It is rare to be in a situation where cost is no object, though it does happen from time to time, particularly with military systems where only the best will do, no matter what the cost.

  It is more usual for there to be a tight budget within which performance must be traded off against features such as reliability, security and size.

- **Performance**

  Response time is very important in all interactions between operator and the computer. There must be some kind of response from the computer within two seconds. This does not mean that the function must be completed in that time, but that the user must receive a signal that his command is being processed. The signal might be a change in the shape of the cursor from arrow to hourglass, or a message box saying "Please Wait!" When retrieving graphics from the database, the system should start to draw on the screen almost immediately, although the complete dataset may take minutes to draw.

- **Compatibility with existing systems**

  If the customer has already invested heavily in computerisation, he will be concerned to protect his investment. Due to the rapid change in technology referred to Section 8.3.1 hardware is obsolete in three to five years. This is recognised in taxation and accounting rules which, in many countries, allow a very rapid depreciation of the capital value of computer equipment. Thus there is no need to maintain compatibility with hardware of this age. However if it is possible to produce an efficient system design which does maintain compatibility, this is to be welcomed.

  Software is another matter - the average life of a software product is much longer than that of hardware, and it represents a much larger investment. Unless an application is being replaced it will continue to be used and must somehow be integrated into the new environment.

- **Scope for future growth**

  Most organisations collecting and processing data experience a continual increase in the size of their data stores, especially if it is necessary to keep the data indefinitely. A survey department or a deeds registry is obliged to keep all past records as these may have a bearing on the present legal status of the land. The system design should cater for the anticipated growth for at least five years.

8.2.2.1 Data Structure

A fully detailed data model cannot be worked out until one knows on which database it will be implemented. With the present state of technology it is fairly safe to assume that a relational database management system (RDBMS) will be used. Because all RDBMS share many common features, a generic data model can be built and implemented on any specific database with very few changes.

In an RDBMS, entities are represented by tables. The rows of the table, or records, represent individual instances of a particular entity, and the columns of the table, or fields, are the attributes which describe the entity. Each record has a unique identifier which distinguishes it from all other instances of the entity. This identifier is called the primary key of the table. For example, the data analysis may reveal entities called 'land owner' and 'land parcel'. The land owner may have various attributes such as name, address, date of birth etc., and the land parcel also has attributes such as area, address, lot number, land use, title document reference etc. An example of a table is shown below:

Table : **Land Owner**

Name	**Address**	**Date of Birth**	**I/C No.**
Jones A C	5 Little Road Rondebosch	20/8/42	107225226
Smith Z A	32 Johns Road Rondebosch	13/7/57	229317436
Talbot M K	13 Foundry Road Salt River	6/11/49	187221847

8.2.2.1.1 Data Dictionary

The **data dictionary** is a document which names and defines the entities and their attributes. This is an important document because many common words are ambiguous. For example in creating the data dictionary for a GIS in Singapore, the word 'area' was found to have five different meanings depending on the department and the context. It could refer to land or building, total floor area or usable floor area, it might include or exclude balconies etc. The difficulty was resolved when each department defined the exact meaning that they attached to the word, with a different term being used to denote each.

In the logical design, the data dictionary should list every table name and every field name with a definition.

8.2.2.2 Computer Functions

The necessary functions have been specified in the User Requirements Specification. This document serves as a reference when specifying system components. The test is whether the proposed system will be able to fulfil the functional requirements.

8.2.3 Technical Design Factors

Computers are at the heart of computer-based information systems, thus it is obvious that computer technology will have a big influence on system design. The limits of technology provide a constraint to system design by limiting design to what is possible.

8.2.3.1 Technology

Changes in information technology are so fast that it is hard to keep up with them. The product cycle time for personal computers is now less than a year. PC's bought three years ago are considered obsolete. Such PC's may not be able to run today's client applications without additional memory, and even then their performance may not be acceptable.

In contrast, the latest technology is relatively expensive and untried in the market.

Figure 8-5 overleaf illustrates how the price of new technology falls as the volume sold increases. The rate of increase in the volume of sales decreases as the next generation of technology comes on the market and eventually starts to fall. At this point sales volume is high but can only be maintained by a rapidly falling price.

Important points to consider when evaluating system hardware are:

- What is the latest technology? Is it still the current technology but with better performance e.g. 80486, 80586, 80686 CPU chips. Or something different e.g. the replacement of pen plotters by ink-jet plotters.
- Is the new technology compatible with existing hardware and software? Sometimes there is a good reason to make a break with the past and to adopt new technology which is not compatible with existing systems. This is certainly the case when moving from main-frame to client/server systems. The only pre-requisite for such a move is that data can be moved from the old to the new system without loss of information.

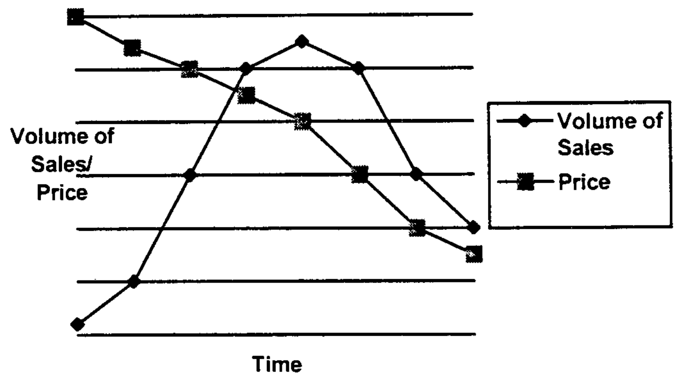


Figure 8-5 The Relationship between Price, Sales Volume, and Time

8.2.3.2 System Configuration - Hardware

Until recently large systems were designed to run on mainframe or mini-computer hosts. Users interacted with the system through 'dumb' alpha-numeric or graphic terminals. For example, the State of Qatar GIS was initially based on a VAX 6000 series mini-computer using a number of Tektronix graphic terminals, likewise the first GIS installation at Singapore Polytechnic was based on Arc/Info software installed on a Prime mini-computer with a number of graphic terminals.

For many reasons computer systems are moving away from mainframe + dumb terminals to the client/server configuration. This configuration moves the processing power to the desk-top computer, while still enabling data in a central server to be shared by everyone connected to the network.

The features of the client/server configuration are :

- Enterprise-wide - all services are available wherever there is a network connection.
- Heterogeneous - the system integrates a variety of different hardware and software systems through the network.
- Distributed data and processing - processing is distributed between clients and servers. In large systems a three-tiered configuration is sometimes adopted which interposes a number of application servers between the clients and the database server.

The advantages of the client/server configuration are:

- Enhanced data sharing - different database systems can be linked
- Integrated services - electronic mail, sending and receiving of faxes, user account management can be done centrally for all users.
- Sharing resources among diverse platforms - printers, plotters, digitisers, scanners and other peripherals can be shared by all the users on the network.
- Data interchangeability and interoperability - with appropriate software, data from different sources can be exchanged and used by clients. e.g. MS-Word documents can be edited on PC's or on Macintoshes, MS-Excel and Lotus-1-2-3 spreadsheets can be exchanged.
- Masked physical data access - the user does not need to know where the data is physically stored. e.g. if a planner calls up the electricity reticulation map to overlay on his master plan, he need not know that he is retrieving data from a server in the Electricity Department.
- Location independence of data and processing - processing can be carried out anywhere on the network, no matter where the data is stored, and can be distributed between client and server, or even distributed to more than one client.

8.2.3.3 Centralised management

The management of a large heterogeneous system is a complex matter. Faults have to be repaired, back-ups of the database taken regularly, users' accounts maintained, new releases of software loaded etc. There is a strong argument for the centralised management of these activities, unless the data is distributed on different servers, each one under local control. In this case the owners of the data on the servers may take responsibility for backing up their data and for controlling access.

System management is a function best centralised and carried out by a specialist unit such as the users' EDP department. Although this is a user function, the system developers cannot forget about it. The development team must propose procedures for system management and put these procedures in place at the time the system becomes operational.

8.2.3.4 System Configuration - Software

The heart of any corporate information system is the database, and GIS is no exception in this regard. In the early days of GIS, developers produced software with embedded proprietary database software such as SICAD-GDB, while commercial applications were being run on relational database management systems (RDBMS) such as Oracle and Informix. Later GIS software was opened to some extent to permit linking graphic objects, still stored in a proprietary format, to non-graphic attributes stored in RDBMS.

There is now a move to store both graphic and non-graphic data in the RDBMS and two or three GIS products are now doing this e.g. SICAD, ArcStorm. The reason for this is that commercial RDBMS provide numerous facilities, not available or difficult to implement, in proprietary systems. Such facilities include importing and exporting data, tracking transactions, committing and rolling back transactions, backing up data, standard structured query language (SQL) and data definition language.

The leading RDBMS are all very similar in technical capabilities, hence the choice would be determined by local support, price, and compatibility with the chosen GIS software.

The factors to take into account when choosing GIS software include:

- GIS vector data structure - layers, objects and tiles
- Ability to integrate raster and vector data
- Analysis capabilities
- Ability to handle large data sets
- Ability to map large areas seamlessly without dividing data into blocks or 'tiles' or mapsheets
- Additional functionality such as digital terrain model (DTM) construction, perspective views and triangulated irregular networks (TIN)
- Data security
- The ability to connect to external databases
- Customisation language

The functionality of the software should be matched with the user requirements specifications to ensure that the software selected performs all the necessary functions.

8.2.4 Specifying the Hardware, Software, and Development Environment

The hardware and software must be able to satisfy the requirements of the logical system design. The actual hardware and software products may be specified by the development team or may be the subject of a competitive tender. In the latter case the logical system design serves as the tender specification. Purchasing is dealt with in Section 10.1.1.

Apart from technical issues there are other factors to consider. These include:

- Support from vendors

  Does the vendor have a reliable and technically competent local agent?

  Is the vendor known to be responsive to customer's problems?

  What is the policy regarding upgrades and maintenance?
- Position of vendor in the market

  Is the vendor a market leader?

  What is the vendor's financial position?

  Is money being invested in improving the product?

A small innovative company may come to the market with a very good product, yet may lack the funds to provide a reasonable level of customer support. It is risky to deal with such companies.

8.2.5 User Interface

For may years the importance of the user interface was not recognised. In fact this is one of the critical points in the system because it is here that people interact with the machine.

It should be remembered that typical system users are not computer experts, nor expert in surveying and mapping for that matter. The users also differ widely in educational levels from draftsmen and operators to senior executives and professionals. Many users, especially those from the senior management level, are occasional users who do not remember commands from one session to the next.

To meet the requirements of both occasional users and regular users the following points should be taken into account when developing user interfaces.

- **Windows-based** - Most people who use PC's at home make use of windows-based software such as word-processors, spreadsheets and games. These people expect the same ease of use at the office as on their PC at home. For example switching from one program to another, or copying a set of Figures from a spreadsheet and pasting them into a word-processor.
- **Following standard style** - Learning is much quicker when the program menus and forms follow a standard style e.g. the main menu starting on the left with 'File' followed by 'Edit', with 'Help' on the right-hand side.
- **Unambiguous menu items** - It should be clear what a menu item does, sometimes a hint box or prompt line can be helpful is clarifying the meaning.
- **Useful prompts** - When the user is required to take some action, the prompt or message must be clear and unambiguous.
- **On-line help** - Context-sensitive on-line help is very important to occasional users. Users in general are very reluctant to start paging through manuals and SICAD and Arc/Info manuals for instance, come in several volumes. Help may go beyond a simple statement of what data to enter, to provide some explanation about the function being performed.
- **Aesthetic design** - The choice of fonts and colours on the screen affects the degree of fatigue and stress experienced by the users while working. Reaction to colours, fonts and screen layout is to some extent a personal matter, influenced by culture.
- **Appropriate** - For operators, the system should only show the functions which the operator is allowed to perform, and should proceed automatically from one function to the next in accordance with the particular work procedure.

Because the user interface is critical to the system, it is essential to prepare a prototype which as many users as possible can try out and comment on. Generally an iterative process should be followed with system design.

Rapid prototyping tools such as Borland's Delphi or Visual Basic allow user interface prototypes to be created within hours, and to be modified interactively with the user.

8.3 Technical Specification

In moving from the logical system to a real information system, a technical design must be produced which covers computer hardware, system software, application software and products which have to be developed. At this point the whole process becomes more concrete, the development hardware and software is known and the logical system design is refined to take account of the actual situation. From the system perspective this is a phase in which the Project Team (development system) has less interaction with the organisation; the users have been involved in the requirements study and the logical system design, it now becomes essentially a technical matter to turn the design into a real system.

There is a tendency to exclude users from this phase because the work is viewed as being technical and thus entirely within the Project Team's competence. (Eason 1988, p.65) refers to this as a *technical-design-centred approach*. Given that the necessary technical expertise resides in the team and that this approach is in line with the industry status-quo, it is a natural way to proceed. However, if there are problems later, for example, existing user applications do not run on the new hardware, the users will say that they were not consulted. On the other hand, decisions with regard to compatibility with existing systems should have been incorporated in the Information Systems Plan with regard to general principles, and in the System Design with respect to details.

Perhaps rather more than with users of other types of information systems, some GIS users, particularly professionals, tend to be familiar with the technology, but lack a good understanding of systems and of system implementation methodology. There is thus scope for productive co-operation between system developers and users, provided the latter are already familiar with the technology.

Eason (1988) makes a plea for a *socio-technical approach* in which non-technical issues are kept in view and addressed through regular interaction between developers. Non-technical users can provide valuable input in the technical design phase in areas such as workstation design, work procedures, etc. For example, a digitising tablet may be a fixed table or an upright board with a variable tilt angle, and it may or may not be back-lit. Electronically, the models are indistinguishable, but from the operator's perspective there is a great deal of difference. It must be remembered that acceptance by the users plays a major part in the success of a system and that it can contribute to overall project success to consult users on such issues.

There are a great many technical issues which must be taken into account when designing the technical specification. Estimates must be made for system growth and system expansion must be planned. It is easy to increase data storage capacity by adding disk drives, but to increase network bandwidth a costly move to new technology may be needed e.g. by replacing co-axial cable by optic fibre and Ethernet by ATM switching. This is particularly true in the GIS environment where increased use of satellite images might result in a vast increase in network traffic. In other words, the technical design should provide an infrastructure to cater to anticipated growth, while the purchase of additional workstations, printers, plotters and disk drives can be left until they are actually needed. Factors to consider include:

- number of users
- data storage capacity
- response time requirements
- location (LAN or WAN - distributed or central database)
- operating system
- database technology

The technical specification sets out specific hardware and software requirements. Hardware performance, software functionality etc. is specified in detail.

8.3.1 The Development Process - Technical Specification

Figure 8-6 overleaf shows the system for preparing the Technical Specification.

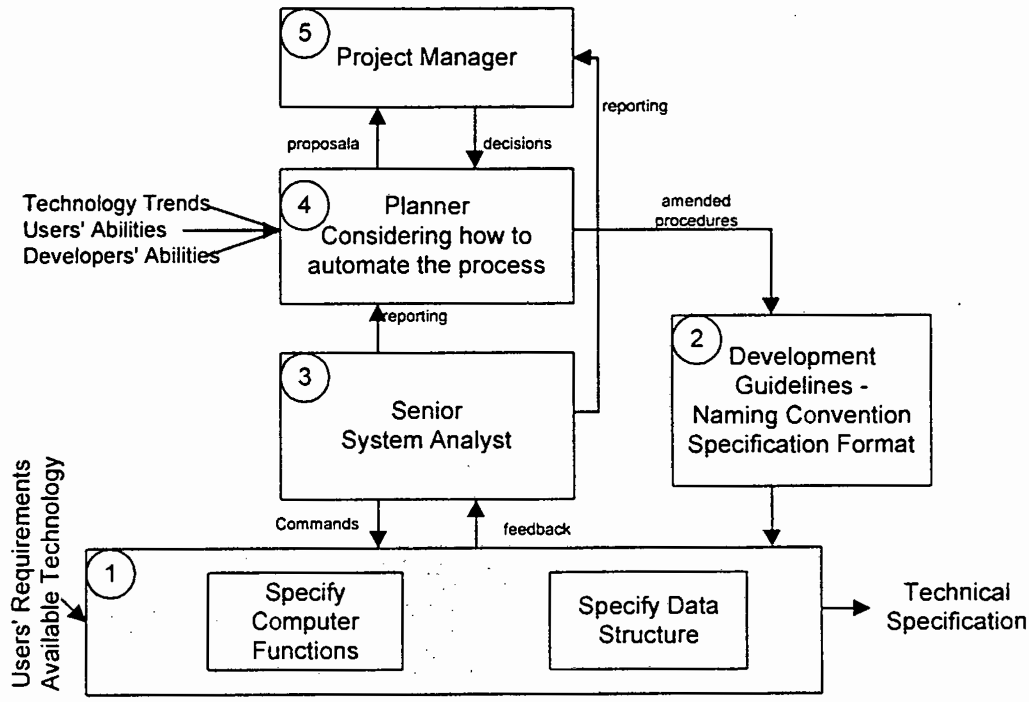


Figure 8-6 Writing the Technical Specification

The different parts of the system each have a specific role to play in order to ensure a successful outcome. The component numbers follow Beer (see p.2-20).

- *System 1* - Operations

  The process breaks down into two main sub-tasks -

  ⇒ specifying functions with respect to proposed hardware and software

  ⇒ defining the data structure

- *System 2* - Co-ordination

  The Technical Specifications are constrained by the Users' Requirements and the system configuration. The layout and format of the Technical Specification is provided by the development methodology guidelines or Quality Procedures Manual.

- *System 3* - Monitoring and Control

  The system design is monitored by the Project Manager. Checks are made for compliance with layout and format, and for correspondence between data and functions definitions with those defined in the Requirements Specification.

- *System 4* - Planning

  There is not much room for innovation in the area of technical specification.
- *System 5* - Executive

  The technical specification is within the control of the Project Manager. All decisions relate to mapping the logical design on to the physical configuration; this will affect the customer if it is not done correctly, but it is not within his competence to make decisions relating to the process.

Table 8-3 below explains the system and its components in more detail.

Process	Technical Specification
Process Description	Preparation of system specification including all hardware and network components, system software, application software. The specification also includes the database structure - tables and fields, and security set up. All the user functions to be computerised are also defined .
Owner	Project Manager
Owner Qualities	An understanding of and experience in the design of information systems development process coupled with the ability to evaluate a technical design from a management perspective.
Actor	System Analyst
Actor Qualities	An understanding of and experience in the design of information systems development process.
Controller	Project Management Committee
Monitoring Process	Review of specification by competent technical experts.
Client	User organisation management.
Client Characteristics	Has good knowledge of business processes, but knowledge of information systems may vary from extensive to nil.
Pre-Conditions	All users who will be involved in the development process must have sufficient training to enable them to play an effective role.
Input	Information from the Information Systems Plan about the business process, development priorities, existing computer systems, available skills. Availability of resources including manpower, work areas, hardware and software.
Output	Detailed specification for building and installing the system.
Post-Conditions	Actual development work can now start.

Table 8-3 Technical Specification

8.3.2 Detailed Functional Specification

The User Requirements Specification defines the functions needed by the users in general terms in such a way that the functions can be satisfied using any of the competing software products in the market. At this stage the actual hardware and software to be used have been specified. The Technical Specification defines the functions are defined taking account of this hardware and software.

The specification defines entities and relations in terms of database tables. Entity attributes are record fields. Each table and field is defined in terms of the actual database software selected. Names of tables and fields follow the naming conventions of the database, and data types are specified in terms of the actual data types permitted by the chosen database. For each function the technical specification will specify which tables are to be opened, which fields will be updated, etc.

8.3.3 Data Modelling

The data model contained in the logical system design is modified to meet special requirements of the specific database selected. In most cases this will be very little, if any, work. It may be necessary to change names of tables or fields to comply with the database rules. It may also be necessary to change some data types to match the types which are available in the selected product.

8.3.4 The Technical Specification

The final step in the planning and design process is the Technical Specification Document. This is the detailed plan which all programmers working on the system will follow. If it is not correct, the system will not be built correctly. It is analogous to an architect's detailed working drawings for a building.

It is important that the specification should follow a standard format so that everyone using it will understand it in the same way. The monitoring process looks not only at the contents of the document, but also at the format and layout.

When preparing technical specifications, it is also important to remember that an organisation's requirements will change over time. New business rules may be introduced, the organisation may go into new areas of business, and so forth. The system built to meet current requirements must encompass as much flexibility as possible to enable it to be adapted to future, and as yet unknown, requirements. To achieve this two things are necessary. The first is a modular approach to system building which confines business rules to small modules with well-defined interfaces. The second is that no data is 'hard-coded' into the system. Parameters are used to set up the business rules, and these can be changed when necessary. A typical example of this would be the rules used to allocate tasks by a workflow engine. The developer also gains from this approach because his generic modules can be re-sold to other customers.

9. THE DEVELOPMENT PROCESS - SYSTEM IMPLEMENTATION

Having designed a suitable computer-based information system, it must be developed and integrated with the daily business activities and tasks of the firm. It is this process which Campbell and Masser (1995, p.6) refer to as 'diffusion'.

Diffusion is the process which results in the technology moving from Hoebeke's innovation domain to the added-value domain, and ultimately to the success of the development project. See Campbell's concept below in Figure 9-1.

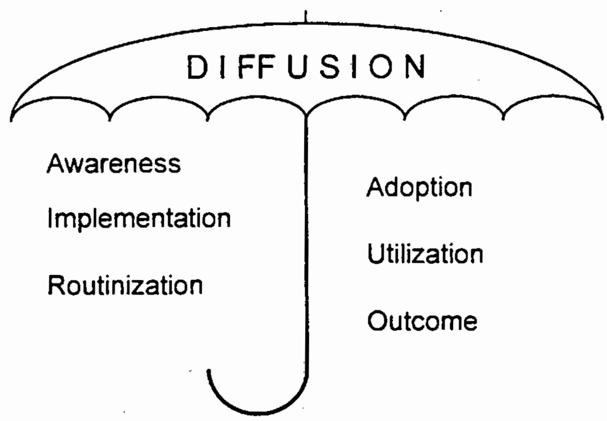


Figure 9-1 A Conceptualisation of Diffusion (Campbell p.6)

- **Awareness**

  All staff whose work will be affected either directly or indirectly by the system should be made aware of the system - what it will do, how it will affect work practices, what the benefits are, etc. This awareness should come about through briefings by management or project staff to ensure that staff are correctly informed.
- **Implementation**

  Implementation is a technical issue which does not affect people outside the project group. It is dealt with in more detail below.
- **Adoption**

  The technology is offered to the users by the innovation domain. It is then up to the users (or potential users) to adopt the technology and make it their own.

- **Utilisation**

  The technology cannot be said to have been fully adopted unless is actually used in the operational environment to assist in business processes.
- **Routinisation**

  Once the technology has been adopted and is used, the final step in diffusion is routinisation. This is the procedure by which the use of the system becomes routine in the organisation. The system is no longer perceived as an innovation but as part of the normal work environment.
- **Outcome**

  The outcome of the system development can be judged by the amount of routinisation that has been achieved. Only if the use of the technology has become routine can the system be judged successful.

9.1 General Considerations

In moving from a technical specification to a real system, one is moving from the abstract to the concrete. This is the stage in which the system ceases to be a set of written documents and becomes an information system with workstations and servers, network cabling and peripherals, operating systems and application systems, databases and communication software. In achieving this transformation there are some practical issues which must be considered.

9.1.1 Purchasing

Within the public sector all over the world, it is normal practice to call an open tender for the supply of system hardware and software. This practice results in a number of tenderers spending large sums of money on tender preparation knowing that only one of them will get the job. A deal negotiated between client and vendor makes much better sense from an economic and technical point of view but can, unfortunately, lead to corrupt practices, and is usually politically unacceptable. The problem is that, even with "open systems", every product has its own individual features which may make it better than competing products for certain purposes. The developer and users may prefer one product, but often end up with the cheapest.

Most large organisations have a 'purchasing system' which prevents technical staff dealing directly with suppliers. When system development is being undertaken by an internal group, perhaps with the assistance of an external consultant, purchases of hardware and software will follow this route. However, when a contract has been awarded to a vendor or system integrator, it will be the responsibility of the project manager to place orders for hardware, software and work to be undertaken by sub-contractors. In doing this the project manager will probably make use of his own organisation's purchasing system.

An important consideration is that, no matter how the hardware and software is purchased, the consultant team should be chosen on their track record and ability to develop a close relationship with the customer.

9.1.2 Prototypes

Rapid application development tools make it easy to "mock up" a user interface very quickly. An iterative process can be followed by producing an interface, discussing it with the users and then modifying it until agreement is reached. This method works better with users who are already familiar with computers and have a mental model with which to compare the prototype presented to them.

An added advantage of this approach is that it provides a chance for interaction between the project team and the users. This interaction builds rapport and keeps the users actively involved in the progress of the project.

9.1.3 Phased Implementation

The problem of commissioning the system was discussed in greater detail in Chapter 7 where a justification was given for phased project implementation. The important requirement is that each phase should be as short as possible, consistent with operational requirements. Each phase should produce something useful to the customer which he can immediately put into operation.

9.2 The Development Process - Building the System

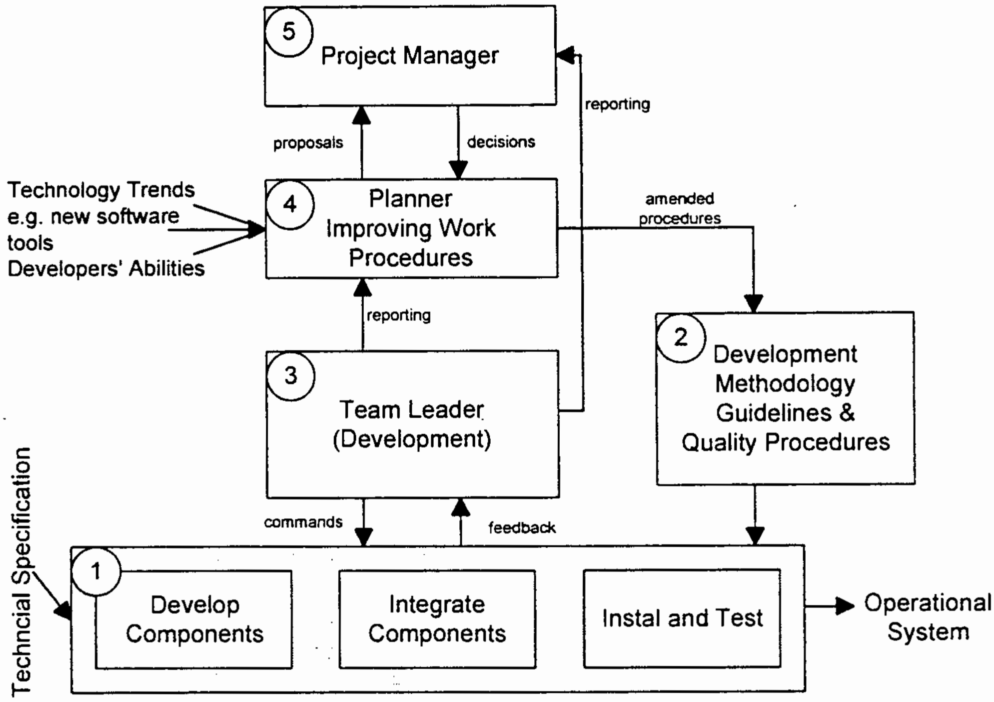


Figure 9-2 Building the System

Figure 9-2 above shows the development process for building the system. The system components work as follows:

- *System 1* - Operations

  The process breaks down into three main sub-tasks:

  ⇒ developing components

  ⇒ integrating components

  ⇒ installing and testing

- *System 2* - Co-ordination

  The development methodology guidelines and quality procedures manual should provide fairly detailed instructions on how to carry out the work. To ensure that the work of a number of programmers can be integrated they must all adhere to the technical specifications, to naming conventions, and to any other specific quality measure such as internal documentation of code, or graphic user interface style guide.

The system may be the work of many, but it should look as though it was programmed by one person. There are many examples of inconsistency in commercial software, e.g. Arc/Info commands require parameters to be separated sometimes by commas and sometimes by spaces.

- *System 3* - Monitoring and Control

  The coding of functions is monitored by reviewing the code and looking at test results of individual functions. The Controller is also responsible for maintaining productivity and therefore must also monitor the number of functions produced by each programmer.

  Each programmer also performs a self-monitoring function by testing each component when he finishes it.
- *System 4* - Planning

  Planning in the area of system building is important, but should be viewed in the long term. Innovative techniques cannot be introduced in the middle of a project. However, it is during one project that opportunities are spotted for innovation in the next project.
- *System 5* - Executive

  The project manager serves as the decision maker for all matters affecting the way the work is carried out.

9.3 Development of Components

A computer-based geographic information system is, by its nature, complex. Typically the software configuration will include one or two operating systems, networking software, a relational database management system (RDBMS) and GIS software. The customisation process is concerned chiefly with the latter. The users have specified the functionality they need and this now has to be programmed.

In the client/server environment, the rule is to do as much processing as possible on the client, leaving the server free to concentrate on database operations. A second rule is to minimise network traffic. This means that operations, which would result in transferring large volumes of data across the network, should be done on the server. For example, sorting a database table on the client would mean sending the whole table to the client even if the user only needed the first ten sorted records. Network traffic would be enormously reduced by sorting on the server and then sending the ten records to the client. All commercially important RDBMS provide a procedural SQL language which can be used to develop functions to be executed on the server. These procedures are stored in the database itself and are called 'stored procedures'.

At the client end, software development includes the user interface and, in the case of GIS, the graphic and spatial data handling functions. Most modern GIS software includes a customisable graphic user interface (GUI) which can also call external programs, for example programs for non-graphic data entry. Many general purpose client development tools are now available such as Microsoft Visual Basic, Borland Delphi, PowerBuilder, Informix NewEra, Oracle Developer2000 etc. All these products are object-oriented and contain special objects for connecting to RDBMS. In satisfying the requirement for open systems, Microsoft has developed ODBC (Open Data Base Connectivity) software which enables a client program to connect to any database for which an ODBC driver is available. In this way development tools which might appear to be proprietary such as Informix NewEra can actually work with other databases such as Oracle or Sybase.

'Three-tier' development represents an emerging trend. The business logic is contained in CORBA or DCOM objects which communicate with both the database and the user interface. These objects are usually installed on an application server. There are several advantages to three-tier development; these include:

- The system can be scaled up by placing more instances of the business objects on multiple servers.
- The number of database connections, and hence the cost, is reduced to the number of business objects rather than the number of users.
- The user interface can be changed without affecting the business logic.

Specialised software for generating reports is becoming a key factor in corporate information systems. Products like Crystal Reports, ReportSmith, and Lightship enable reports to be prepared using data drawn from different database systems. Using the technique known as Computer Output to Laser Disk or 'COLD', large reports can be written to laser disk rather than using reams of paper. Each user who needs a report can then view it on his workstation or print the part in which he is interested.

9.3.1 Coding of individual computer functions

Each function should be specified so precisely in the Technical Specification Document that a programmer knowing nothing of the project or system being developed would be able to program the function. At this point it becomes clear that programming is a relatively minor activity when the specifications are properly written. In fact, major cost savings in software development are possible if program coding can be left to junior staff or programmers working in presently low cost countries such as India or China.

9.3.2 Testing individual functions

Functions which read from or modify a database, cannot be tested with a test database. One of the first implementation tasks therefore, is to create a database using the structure defined in the technical specifications document. A limited amount of test data must also be entered. This data must be realistic to ensure that none of the constraints defined in the specifications are violated.

It is usually necessary to set up a test user interface environment from which the function being tested can be triggered.

9.4 Integration of Components

In the past, users interacted with a large system through a command line. A simple command processor read each line typed in and started the right sub-function. This is no longer acceptable. With the graphic user interface, functions are triggered by clicking on a menu item or icon.

9.4.1 Development of global system framework

The global system framework holds the whole system together. It is the software which links the graphical user interface to all the database functions, and provides the facility for one function to link to another.

Security is an important function of the global framework. A single system log-in is important to the user who does not wish to remember several passwords for each server or database. Thus the user does not connect directly to the database, but only through the framework program which also controls the access rights for each user or group of users.

9.4.2 Integration

Provided that the interface between the framework and the components was correctly specified in the Technical Specification, integration should be a straightforward task. In practice this is not always so because individual components which function perfectly by themselves may not operate correctly in association with others.

9.4.3 Testing of entire system

Testing of the entire system can take place once all the modules or components have been fitted into the framework. The test database required for user acceptance testing, described in Section 9.6.2, may also be used for the developers' preliminary testing of the whole system. This testing phase is in fact a rehearsal for the actual user acceptance test. The developers hope that most of their mistakes can be cleared up before the users get to see the system. Normally the users will not give their test data to the developers before the user acceptance test in case the developers tailor the system specially to handle this data. The developers therefore must come up with their own test data.

9.5 System Installation and User Acceptance

The final step in the development cycle is the installation at the users' workplaces, user training, and the switch over to the new system.

9.5.1 Installing the system in the operational environment

Once the system has been fully tested by the developers, the hardware must be installed. This may involve network cable laying, setting up a computer room for the server, putting PC's and workstations on the users' desks etc. If there are existing computer systems, the chances are that the infrastructure is already in place.

9.5.2 System testing with realistic test data

The System Test Plan was referred to briefly in Section 7.2.6. The responsibility for user acceptance testing falls largely on the users. The System Test Plan should specify the functions and cases to be tested and the expected results. The requirements specification provides a guide to the functions to test, and users must supply input data covering as many different cases as possible, based on their experience. A key part of the testing process is a test database which should contain a realistic cross-section of the actual data, covering as many different cases as possible. For example the function in a cadastral GIS, to update the database when a sub-division is processed, may work perfectly with modern accurate survey data, but fail when applied to data taken from old scale diagrams.

During the testing phase, an environment similar to the operational environment should be set up. Each test will be performed in accordance with the Test Plan and the results, including time taken, will be documented. All functions which fail are referred back to the developers to correct, after which the test is performed again.

9.5.3 User Acceptance

Once the test has been completed and every function has passed, the user should give a provisional acceptance of the system. 'Provisional' because the system has been tested under slightly artificial conditions with data which, however skilfully chosen, will lack the range of real data. Final acceptance might be given after the system has been running 'live' for a period of six months to a year, depending on the size of the system. During this period the developers should be available to remedy such defects as come to light.

9.6 Operational Use and Maintenance

It has been stressed above that the introduction of a corporate information system changes an organisation. The computer system produces fundamental changes in communication links, in access to, and availability of data and in speed of operation. It also becomes possible to perform tasks which were impossible before. The nature of computer technology too, is such that further opportunities for computerisation constantly appear, as the technology advances.

Hitherto the introduction of a new information system has generally been seen as the imposition of a new system on the organisation. Any imposition produces a negative reaction which may in extreme cases cause the new system to fail. By visualising the introduction of the new system as a transformation of the organisation, a confrontational approach is avoided and a strategy can be developed to achieve a smooth transformation.

Within a stable organisation there is always resistance to change. Various methods can be adopted to promote and facilitate change. Some of these were dealt with when discussing the design stage:

- Keep the users informed and involved throughout the design and implementation phases.
- Address the concerns of those employees who fear not being able to adapt to the new technology. Allow an extended learning period when necessary.
- Design an effective user interface to make the system easy to learn and easy to use.

9.6.1 Data Conversion Strategy

In most cases, particularly with geographic information systems, data conversion is a major task which may continue for many years. Clearly it is not possible to wait until all the data is ready before bringing the system into use. At the same time it is not possible to use the system without data. The best solution is to divide the total area into a number of divisions, each division being of such a size that the data completion can be completed within a fairly short time, preferably less than a year. Where possible, these divisions should coincide with administrative boundaries, see Figure 9-3 overleaf. Within the selected division then, all data will be captured.

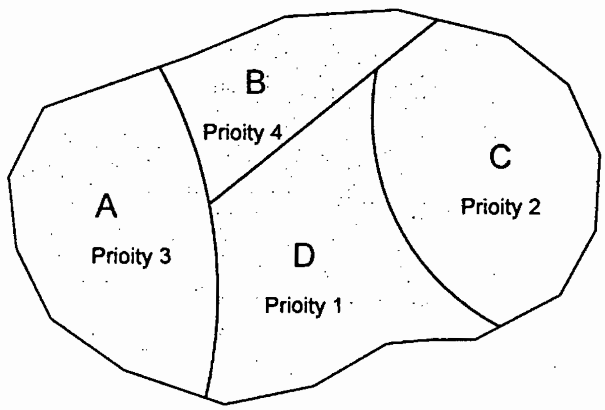


Figure 9-3 Priority Areas Assigned for Data Capture

The problem with this approach is that people with projects in non-priority areas will clamour for their needs to be taken into account. Generally it is a mistake to deviate from the planned priorities to accede to these requests because the end result is many small scattered data sets which preventing the GIS from being utilised fully anywhere.

9.6.2 Data conversion/ loading

In many cases the initial data is not captured on the new system. For example maps may be digitised using PC's with AutoCad or MicroStation. The data collected must be converted to the format of the GIS and the data loaded into the database. This is a 'one off' activity which should be left to the developer to handle.

9.6.3 Parallel Operation

It is common practice to keep the existing (manual or computerised) operational system working in parallel with the new computer system during the testing phase. However, once the system has been accepted, there should be a complete change over to the new system. If the users are not confident about this, the user acceptance stage should be extended until they are.

Due to the phased nature of data conversion and loading, both systems will be in parallel operation for some time - but not processing the same data.

9.6.4 Switching Over

Between the time that the data capture is completed and the time that the system goes 'live', there may be changes to the data made by the manual system. These must be recorded and entered into the computer.

9.6.5 Training

Training has been mentioned before. It is a vital activity, and targeted at the various activities in each phase of the development process.

9.6.5.1 Training for Management

It has been stressed that the support of senior management is critical to the success of the project. To give this support and to make informed decisions most managers need training. This is needed right at the start of the information systems planning phase so that they understand exactly what is being proposed to them and what the implications are.

The training should give the management needs a high-level understanding of the system, and in particular of:

Services the system will provide

Systems are very often over-sold during the pre-sale phase. When the gap between reality and the story told by the salesman or system champion becomes apparent, disillusionment is a likely outcome. For this reason it is important to keep senior management informed about the proposed system at regular intervals throughout the design and implementation phase, through seminars and briefing sessions.

Costs of implementing the system

Costs shown in the budget for software, hardware and consulting services seldom represent the true costs of the system development. There are many hidden costs such as the cost of internal EDP staff and system users who are involved in the system design stage, the costs of parallel operation, data conversion, loss of production while learning etc. Effective decision making depends on management having an awareness of these factors.

Benefits of using the system

Management can only promote the system effectively if they have a clear understanding of the benefits it will provide - in terms of improved work performance, better access to information, better data for decision-making etc.

Impact of the system on the organisation

This is the area which should be of most concern to management because it will affect the way they make decisions and the way they manage the business processes. Only when the managers are informed about the role the computer system will play in the organisation can they consider its impact. This issue should be dealt with during the discussions on the Information Systems Plan. In other words, it is the duty of the organisation specialist or IS Planner to make sure that the managers understand the implications of the proposals put to them. Failure to do this will result in problems later in the project when managers say "but I didn't realise that this would happen."

9.6.5.2 Technical Training

There is no point in putting members of the customer's staff in the development team and just hoping that technology transfer will take place. It may take place if the staff are well motivated and have the right technical background. However, it is much better not to leave things to chance and to give technical training to all the customer's technical staff attached to the project team. This gives them specific knowledge of the project hardware and software and ensures a certain level of understanding between team members.

Courses at different levels may be given at various points in the project. It is a good idea to start with an overview of the products to be used as soon as these have been specified. Later, before development starts, in-depth training can be given in specific areas needed in the system development e.g. use of the procedure language, design of the user interface etc.

9.6.5.3 Training for Operators

The operators are the people who use the system day in and day out. It is important that they find the system easy to operate and are able to learn to do so reasonably quickly. The importance of the graphical user interface and its role in shortening the learning curve, was discussed above in Section 8.2.3.

9.6.6 Maintenance

A new operational system will soon fail if it is not maintained. Hardware will fail from time to time and need to be repaired or replaced

9.6.6.1 Defect Management

Even after the user acceptance test has been completed, it is very probable that further defects will come to light. This is because of the impossibility of testing all the possible values and combinations of input data. Defects naturally cause annoyance to users. This can be alleviated if the developers respond promptly so that the user feels that something is being done about the problem. On the other hand, developers become annoyed when faults are reported which they cannot reproduce. They suspect that the faults are not genuine but result from wrong operations. Developers are also annoyed by the same problem being reported several times.

To resolve these problems, a system must be set up to deal with defects. A typical scenario is that an operator who encounters a defect will report to his supervisor. The latter then attempts to repeat the fault. If he is successful he fills out a defect report describing the problem, the operation being performed at the time, the dataset in use, the sequence of commands and any other relevant facts. This form is then sent to the development team who take the necessary steps to correct the fault. By ensuring that all defects are reported through one channel, repeated reporting of the same problem is avoided, and by recording every defect it is possible to check whether it has been fixed or not. The record of defects also provides useful statistical evidence about the technical competence of the development team.

9.6.6.2 Configuration Management

In order to manage a system effectively the system manager should know the hardware configuration of every computer, the software running on each, and the version of the software. If this information is available, the introduction of new software can be planned rationally - the manager knows which computers will run the new software, which ones will run it after specified upgrading and which will not be able to run it. He can thus plan hardware upgrades and budget to replace computers which do not support the new software.

In a large heterogeneous system it almost impossible to maintain complete configuration information. In the ordinary office environment, peripherals such as CD-ROM drives, tape drives and removable hard disk drives are frequently moved from one computer to another. Memory too, is often 'borrowed' to run special software. Sometimes users add new software for special purposes and may even upgrade or modify the operating system. Mostly these changes are made locally without informing the system manager, making the task of configuration management impossible. In case this is seen as an exaggeration, not long ago in the office of one multi-national IT company, it was only possible to determine the configuration of a workstation worth several hundred thousand dollars by taking the back off and looking inside.

When the users are less sophisticated, control is easier. Unauthorised changes of hardware can be restricted by sealing the computer cases and giving only the system manager and his staff the authority to break the seal. PC's without removable disk drives (floppy or stiffy) limit the possibilities of introducing unauthorised software. Finally, memory-resident programs which are loaded when the computer is booted up, are available. These programs will log and report all activities on the computer to the system manager when interrogated via the network.

Apart from tracking changes to the configuration, the system manager must ensure that all authorised changes are recorded. A database system provides the most appropriate way to do this.

Loading new software on perhaps several hundred PC's can also be a major task. This can be automated using memory-resident agent programs on the PC's. The software is then distributed from the central server via the network and installed automatically by the agent.

9.6.6.3 Upgrading the System

Once the system is in operation, users will start to think about what else they would like the system to do for them. A feedback loop operates to drive expansion of the system. Once they have their hands on the system, users put their imaginations to work to think about what else the system could do for them. The next step is to discuss the new requirement with the developers: what was not feasible earlier may now be possible, due to changes in technology. The customer must retain control over system enhancements and this can be done by putting a change request system in place.

Typically users put up requests for system changes or enhancements through their management. The management meet with the developers who assess the feasibility of the request and quote a price for doing the work. Once the quotation is accepted, the formal procedure for development (including documentation and testing) outlined above is put into operation. In the case of minor changes, the change is documented by amending the existing system design documents. Major changes or enhancements may be treated as new projects.

10. CASE STUDIES

In this section, three projects, one in Singapore, one in Malaysia and one in Indonesia, similar in concept though not in scale, will be examined as to how the theory developed above relates to actual experience.

10.1 The Cases

The writer was closely associated with the three cases studied - as a colleague of the developers, as a project manager, and as the principal consultant. He thus has an intimate knowledge of each project. The first two projects were undertaken before the ideas put forward in this thesis had been developed; in fact the experience gained in these projects led to the development of the ideas. The projects are used to illustrate the dangers of a 'hard' systems approach and of lack of awareness of, and insensitivity to, a different culture.

The third project, the Federal Administrative Centre Information System (FACIS), started after most of this thesis had been written. As principal consultant, the writer was in a position to influence the direction of the development which has been carried out along the lines advocated here. The starting point was an organisational study followed by the production of an Information Systems Plan (ISP). Based on the recommendations of the ISP, the first phase of development is almost complete at the time of writing.

10.1.1 Integrated Land Use System (ILUS) - Singapore

In terms of size and scope, ILUS is a large geographic information system. More than R 150,000,000 has already been spent on system development. The system has more than two hundred users and integrates office automation software, workflow management, and spatial and non-spatial data to form a truly corporate information system. The system processes transactions for development applications, provides planners with information to support decisions and furnishes executives with information on which to base long-term planning.

In the early 1980's a working group comprising representatives from the Singapore National Computer Board (NCB) and the Ministry was set up to investigate the possibilities of introducing GIS into the Ministry of National Development. By 1988 a decision had been taken to proceed and tender documents were prepared.

10.1.1.1 Objectives - ILUS

The requirements set out in the tender documents were:

- to carry out an organisation and methods (O&M) study,
- using the results of the O&M study, to detect and correct weaknesses in operating procedures,
- to prepare an information systems plan (ISP) prioritising application development
- to develop four application sub-systems in line with the ISP.

In addition, a pilot application system was to be developed in parallel with the O&M study to provide a test-bed for the system designers' ideas.

These requirements were met in full but because of changes in technology, when the system eventually went 'live' in August 1994, the hardware and software had completely changed from that envisaged at the start.

10.1.1.2 Configuration - ILUS

As mentioned above, the configuration changed radically over the length of the development period. The system as initially planned was based on a main-frame computer connected to a number of graphic workstations. Several alpha-numeric terminals were also used for programming and non-graphic data entry. The initial configuration used for the pilot project is illustrated in Figure 10-1 below.

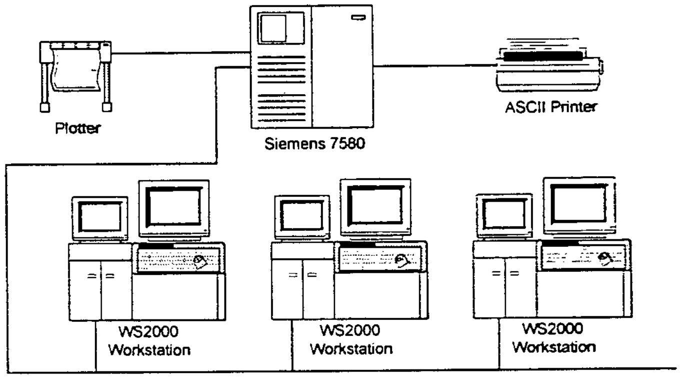


Figure 10-1 The Initial System Configuration

By the end of the pilot phase, the workstation and GIS technology had undergone radical changes. GIS was moving away from main-frames to Unix workstations operating in client/server mode.

Porting the GIS software to Unix involved a radical re-design. The proprietary main-frame database was replaced by a commercial relational database (Informix or Oracle) and was used to store both the non-graphic and the graphic data. This was a major step forward in GIS technology.

These product changes explain the changes to the configuration, which is now completely Unix and DOS-based, as shown in Figure 10-2 below. There are about 40 workstations which can be used for graphic editing, and over 200 PC's which can be used for non-graphic data entry and for viewing and querying graphic data.

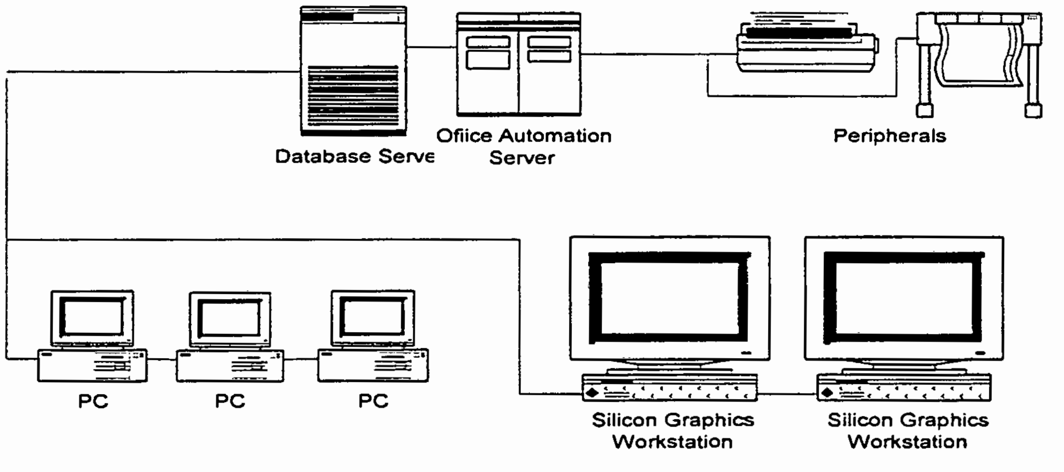


Figure 10-2 ILUS Hardware Configuration

The move to the open platform was not, of itself, sufficient to keep the project on track. A major innovation was made by providing a common user interface and navigation system for the whole system. This enables users to launch all the programs they need from one user interface with a single log-in.

The navigation system has several interesting features:

- The user interface is uniform on Unix and MS-Windows platforms.
- Single log-in gives access to all authorised functions i.e. after logging-in there is no need to log-in again to other servers for database or e-mail connections.

- Every user has an individual user profile. The icons and menus show only the functions which the logged-in user is authorised to perform.
- On logging-in, the user is presented with a window listing the tasks waiting for him to do. This list is generated by the work flow management system project event monitor (PEM). Clicking any item in this window starts the function needed to do that task.
- Items in the PEM window may be jobs sent by other users, or may be triggered automatically by the system. e.g. if an applicant or another department has not responded to a query within a certain period, an automatic instruction to send a reminder letter is generated.

10.1.2 Batam Industrial Development Authority GIS - Indonesia

The Batam Industrial Development Authority GIS (BIDA-GIS) is a small project in comparison to ILUS. Expenditure on system development thus far amounts to about R20,000,000. This is more typical of the size of system being introduced widely in local authorities throughout Europe (see Campbell 1995). Campbell (p.93) reports that the majority of GIS studied in the UK had less than six terminals.

Development was commenced in 1992. The system took place in phases in line with the available budget.

10.1.2.1 Objectives - BIDA GIS

The immediate objective of BIDA-GIS was to reduce the time taken in processing applications to lease industrial land and set up industries. At the commencement of the project the process was lengthy and carried out partly in Batam and partly in Jakarta. Typical cases took between six months and a year to receive approval. At this time it was possible to obtain industrial premises in Singapore within two weeks, and lower cost Malaysian development areas in Johor, Penang and Melaka were also processing applications much more quickly. This resulted in foreign investment going to Singapore and Malaysia rather than to Batam.

It was felt that by automating the processing of applications, the approval of leases could be speeded up and this coupled with the other investment incentives offered by Batam, would be sufficient to ensure a fair share of foreign investment capital for Batam.

The initial objective then, was to develop a system both to automate the processing of land allocations and to provide senior management with immediate reports on the status of any particular piece of land.

10.1.2.2 Configuration - BIDA GIS

The system is still under development. At present two phases have been completed. The third phase has been planned but has not yet been started.

Phase I was a pilot phase designed to introduce GIS to the organisation. The pilot project was developed using a small main-frame database server with four graphics workstations. A PC was provided for data preparation and an electrostatic colour plotter was installed for output. The configuration is shown in Figure 10-3 below.

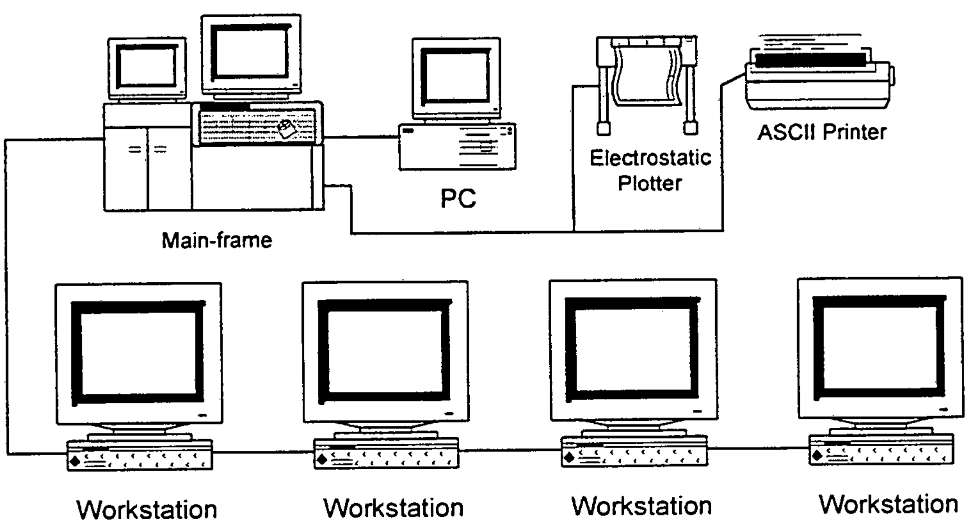


Figure 10-3 BIDA GIS Phase I System Configuration

In the second phase the main-frame database server was replaced by a Unix server running the Informix relational database management system, while each workstation became a client to the server, running its own copy of the GIS software. A similar system was set up in BIDA's Jakarta office. This system has the same software configuration as the system in Batam and the two are connected by a 128k bps VSAT link. This link also handles telephone communication between the offices as shown in Figure 10-4 below. The database is mirrored in Jakarta to enable officers in the Jakarta office to access up-to-date information in real time.

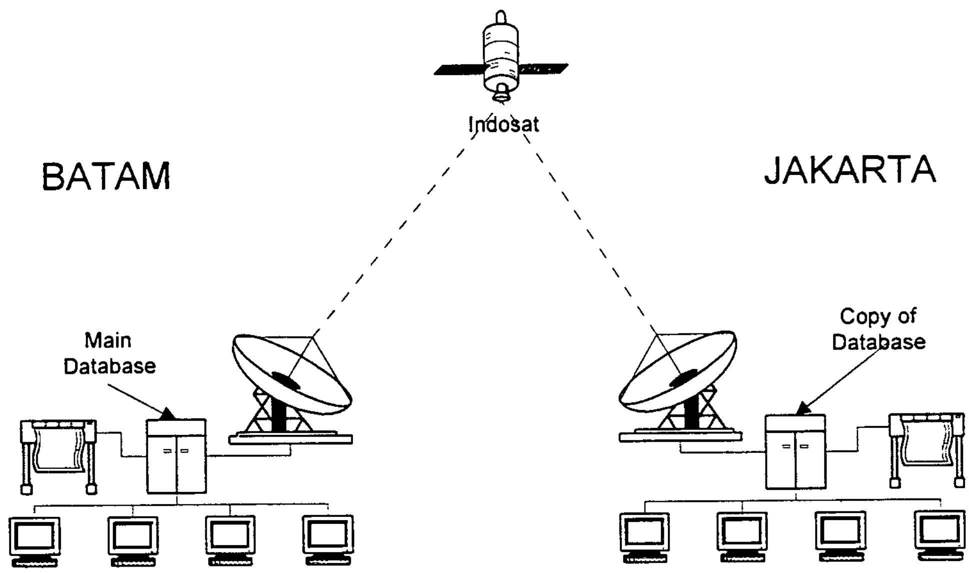


Figure 10-4 The Link between BIDA's Offices in Batam and Jakarta

10.1.3 Integrated City Management System (FACIS) - Malaysia

FACIS goes beyond being a large geographic information system. It was conceived as a complete integrated City Management System. The first phase of development comprises the following application sub-systems:

- <u>Development Planning</u>
  This system handles the preparation of the Master Plan and detailed Urban Design Guides (UDG). These form a set of databases which are part of the overall corporate database.

- <u>Planning Permission</u>

  This system handles the complete workflow for the examination and approval of development plans. This includes registration, billing for application fees and development charges, retrieval of information from the database to support the planners' decisions, such as zoning, current land use, permitted plot ratios, decisions on neighbouring land etc. Checking for many UDG requirements such as building set-backs, height restrictions, parking lot provision, open space provision, plot ratio, etc. is done automatically by a sub-system called the 'Planning Expert'.

- <u>Building Control</u>

  The Building Control System handles the complete workflow from the submission of building plans to the issue of the certificate of fitness to occupy the building. The system checks the plans against the planning permission.

- <u>Land Management</u>

  In Malaysia land is a State government matter, but the relevant State authority has delegated the management of the cadastral system within the boundaries of the Authority to the Federal Administrative Centre (FAC) Authority. The system handles all aspects of land registration and cadastral mapping.

- <u>Billing and Collection</u>

  This system is a consolidated billing system to manage all money owed to the Authority. In Phase I of the project this is mainly limited to application and processing fees for development applications, land premiums and land taxes.

- <u>Legal Database</u>

  The legal database contains hypertext versions of all legislation including laws, by-laws, rules and regulations. The system uses Intranet to provide access to relevant legislation on-line from any officer's desk.

These systems are connected by, and built on, a corporate communication system connecting to a corporate database and managing workflow and documents. This is called the Enterprise-wide System (EWS).

As will be seen in Section 10.1.3.2 below, the system is large. Phase I will have over two hundred users and a diverse range of applications. The cost up to the end of Phase I is about R50,000,000.

The EWS is a key part of the system. It provides communications not only inside the organisation but also with external parties such as government departments, professionals (architects, engineers, surveyors), and the general public. It also manages all the Authority's documents including maps and plans. Incoming correspondence and paper are scanned and stored in image files. The Digital Signature Act passed in 1997 by the Malaysian Parliament allows documents to be submitted electronically with an electronic signature to guarantee authenticity.

The EWS also manages workflow, assigning tasks to officers in accordance with the rules laid down by the organisation. This makes it possible for supervisors to monitor the progress of every job. Members of the public are also able to query the status of their applications or bills via the Internet.

10.1.3.1 Objectives - FACIS

The Malaysian Federal Government has established an area called the 'Multi-media Super Corridor (MSC) between the capital, Kuala Lumpur, and the new International Airport at Sepang about fifty kilometres to the south. This area is being promoted as a world centre for information technology development. Special concessions are available to companies which set up businesses in this area. The government is promoting the MSC in Europe and the USA and trying to attract the world's leading IT companies.

To give impetus to the MSC, and at the same time to reduce traffic congestion in Kuala Lumpur, the government decided to establish a new Federal Administrative Centre (FAC) at Serdang about 30 km south of Kuala Lumpur, right in the middle of the MSC.

In 1995 an Act of Parliament established the Federal Administrative Centre Authority as the local authority to be responsible for the development and management of the city. The city is being developed on a 'green field' site, and is conceived both as a 'city in the forest' to reflect environmental concerns and provide a pleasant environment, and as an 'intelligent city' to reflect its position at the heart of the MSC. The FAC is envisaged as a showcase in which Malaysia can present its achievements to the world.

One of the focuses then, of the FAC Authority, is developing and adopting 'electronic government'. As a new authority, FACA does not carry baggage from the past. The key members of the team leading the development were hand-picked by the Prime Minister and very few came from municipal posts. They were thus able to approach the task of managing a city from a fresh vantage.

It would have been easy for the new authority simply to adopt a structure from an existing municipality such as Kuala Lumpur, however it did not do this. One of its first steps was to appoint a firm of management consultants to devise a suitable structure. The consultants studied all relevant legislation to determine the exact legal duties and responsibilities of a local authority and then proposed a structure to meet these responsibilities.

The information system, FACIS, is intended to be an advanced integrated system, linked by broadband communication to other government departments and to the public. It will provide a model for electronic government in Malaysia.

10.1.3.2 Configuration - FACIS

FACIS is a large system. When Phase I is complete the system will have over 200 users. Recent improvements in PC performance meant that it was not necessary to make use of any Unix workstations. Intel-based PC's are now able to handle all graphics processing. The desktop workstations all use either the WindowsNT or Windows95 operating system. The configuration does include two Unix-based computers. One was already being used by the Corporation and has been re-deployed as an e-mail server. The other Unix computer is the corporate database server. There is general agreement that WindowsNT is not sufficiently robust to support a large database system.

The configuration includes a number of WindowsNT servers. There is an application server, a workflow server, a document management server and so on as illustrated in Figure 10-5 below.

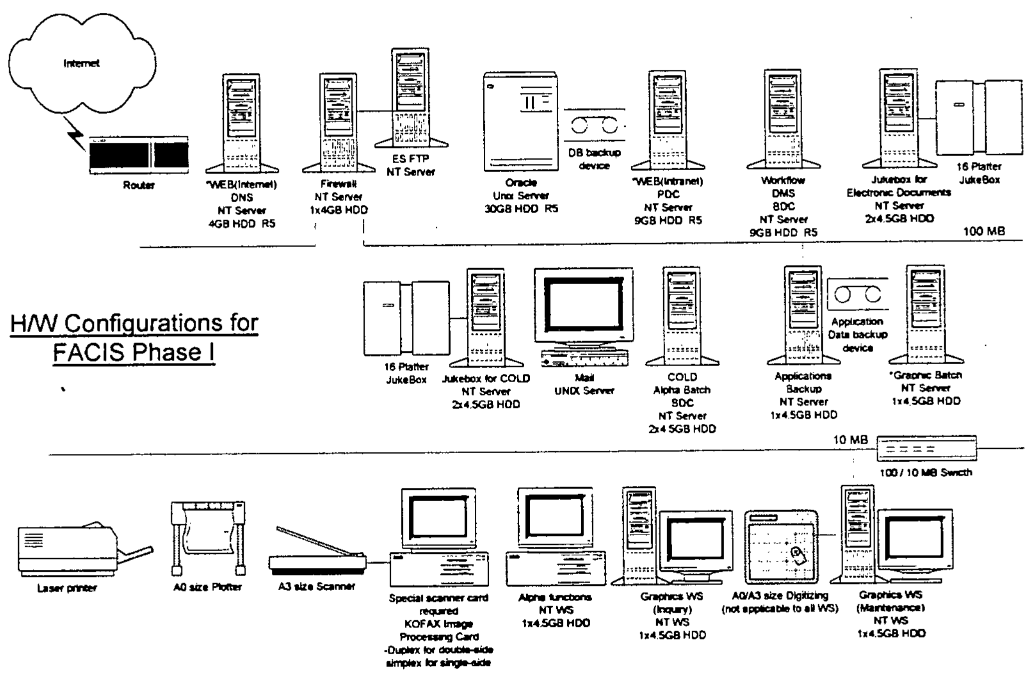


Figure 10-5 Configuration FACIS Phase I

10.2 Cultural Analysis

It has been stressed above that the national and corporate cultures have a major impact on system development. It is important therefore to look at the salient features of each culture to identify those favouring the adoption of information technology, and those resisting its adoption.

The conceptual framework proposed by Davies (1989) for the interpretative analysis of organisational culture and illustrated in Figure 3-6 on page 3-20 is used.

The steps in carrying out this analysis are:

- Identifying the ambient society's cultural, social, and political behaviour,
- Understanding the organisation's history and vision,
- Understanding the technological and economic environment in which the organisation operates.

This information is then used as a basis for making sense of the organisational culture. This in turn supports and legitimises the social structure, policies and processes of the organisation which Davies calls the 'socio-structure'.

The socio-structure in turn creates the norms, status and roles of the individual actors who posses knowledge, values, needs, expectations and motives.

This analysis is applied to the case studies to give an understanding of the system development environment.

10.2.1 Singapore

10.2.1.1 Background - Singapore

Singapore is a very small country covering just 625sq km at the southern tip of the Malay Peninsular. It is an ethnically mixed nation of about three million people, 75% Chinese, 15% Malay, 8% Indian, and 2% others. As a former British colony the country has inherited a British legal and administrative system. The working language of government and administration is English. This is also the medium of instruction in schools and universities.

The country was extremely fortunate in having an exceptional leader for its first thirty years of independence. He was dedicated to rooting out corruption in administration, to providing a decent home for every citizen and a clean green environment. The combination of the British respect for the 'rule of law' with the Confucian values of hard work, self-reliance, respect for elders and those in authority and for learning has produced a prosperous, disciplined society.

10.2.1.2 Culture - Singapore

The cultural environment in Singapore has been shaped to a large extent by the majority Chinese and by the British colonial heritage. The British cultural legacy to Singapore is not the liberal permissive culture of present day Britain, but the

Victorian culture of hard work, thrift, self-improvement, discipline and respect for the rule of law. The Chinese immigrants brought Confucian values of respect for those in authority, respect for one's elders, hard work, love of learning and self-reliance within the extended family or clan. As the Chinese are dominant in terms of numbers and economic power their cultural values have, by and large, been adopted by the population as a whole.

10.2.1.3 Economic and Technological Policy - Singapore

Singapore has a very open free market economy. Competition and innovation are encouraged in all walks of economic life. Singapore has thrived by encouraging foreign businesses to establish offices and factories in Singapore. About half the population is employed by multi-national companies. These companies are attracted by an excellent physical infrastructure, a well-educated work force and an efficient and clean administration.

As the country's only resource is its people, a relatively high proportion of the national income has been devoted to education. Steadily rising educational levels have resulted in a systematic shift from labour-intensive, low skill work to work requiring a high skills level and bringing greater added value.

In the move to a high technology economy nothing has been left to chance. Economic plans are formulated for both short and long term and are continually revised in the light of changing circumstances.

It may be imagined that information technology would play a key role in such a society and this is the case. In 1981 the National Computer Board was established to plan and implement the computerisation of the civil service. An important element in this process was manpower planning to meet the needs of all the proposed computer systems. A ten-year forecast was made of the information technology (IT) manpower requirements for both the government and private sectors. Discussions were held with educational institutions to ensure that suitable courses were put in place to provide sufficient graduates at technician and professional level. In retrospect it can be seen that this plan has been extremely successful and there is now a solid core of Singaporean IT professionals working in neighbouring countries as well as at home.

The Integrated Land Use System forms part of the civil service computerisation programme.

The government has fostered a spirit of innovation, particularly in government departments, statutory authorities and government-owned companies. These organisations employ the brightest young graduates and are always seeking ways of improving performance. For this reason there is a very positive attitude towards the introduction of information technology.

10.2.1.4 The Organisation - Urban Redevelopment Authority

The Urban Redevelopment Authority (URA) is a Statutory Authority reporting to the Minister for National Development. The URA has several responsibilities including:

- **Planning**

  The URA Planning Division is the Planning Authority for Singapore. It has the duty of preparing a Master Plan for the island showing land use zoning. This plan must be updated every five years.

  Large scale 'micro-zoning' plans are prepared which indicate detailed land use zoning and building height restrictions.

  Development Guide Plans (DGP) are prepared on a district by district basis to indicate the direction which development or re-development will take.

- **Development Control**

  All applications to develop land, whether they involve sub-division or not, must be submitted to the Development Control Division. The applications are checked for compliance with zoning, height restrictions and plot-ratio (this is the ratio of the proposed built-up area to the site area). In considering applications, planners also give weight to site access and traffic flow, parking, social needs and decisions on previous similar applications in the same area. If an application is refused, an appeal procedure is open to the applicant.

- **Land Safeguarding**

  Government departments notify the URA of their likely future land requirements. These sites are marked so that, in the event of an owner applying for development permission, the department concerned will be notified and can take action to acquire the land.

- **Car Park Management**

  There are a large number of public car parks in Singapore. The URA Car Parks Division is responsible for their maintenance, for setting parking fees, for the sale of parking coupons and for the imposition and collection of fines for infringement of parking regulations.

- **Sale of Government Land**

  The bulk of undeveloped land in Singapore is State Land. Parcels for commercial, industrial and residential development are sold from time to time to stabilise the market. For example when prices of residential land are rising rapidly, the URA releases more land for residential development.

The Public Works Department (PWD) is a department within the Ministry for National Development. Two branches within the Department are closely involved with land and development, and both are participants in the Integrated Land Use System (ILUS). These are the Roads Branch, responsible for design, construction and maintenance of all public roads in Singapore, and the Building Control Division, responsible for making and enforcing building regulations. See the organisational structure in Figure 11-1 below.

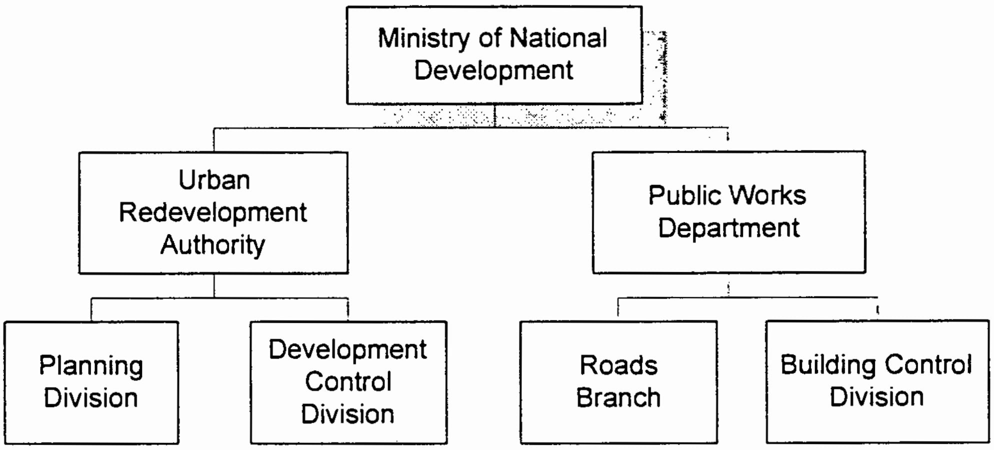


Figure 10-6 Organisational Structure of ILUS User Departments

10.2.2 Indonesia

10.2.2.1 Background - Indonesia

In contrast to Singapore, Indonesia is a very large archipelagic country comprising over 13,000 islands and extending in longitude from 94°E to 142°E, and from 6°N to 12°S. Its population of more than 200 million comprises many ethnic groups belonging to the Malay and Austronesian races. The Javanese form the largest ethnic group and play an important role in the civil and military administration. A former Dutch colony, Indonesia achieved independence in 1949 after a bitter struggle against the Dutch.

In the first years after independence separatist forces were active in West Sumatra, Aceh, Sulawesi and Moluka. To suppress internal separatist groups, the army took a prominent role in the administration. It still retains this role.

Batam Island, the site of the case being studied, lies in the Riau Province about 20 kilometres from Singapore. Until 1975 the island was sparsely populated and quite undeveloped. In that year the National Oil Company (Pertamina) decided to establish a base on the island for servicing off-shore oil fields to the north. Limited development followed this move, but in 1984 a cabinet decision was taken to develop Batam as a free port and centre for manufacture of 'high-tech' goods, primarily for export. The Batam Industrial Development Authority (BIDA) (Otorita Pengembangan Industri Pulau Batam) was established as a special agency reporting directly to the president, with the Minister for Research and Technology as head.

10.2.2.2 Culture - Indonesia

The Indonesian population comprises over two hundred ethnic groups each with its own culture and language. The Indonesian language is a key element of the national culture. It serves as the primary integrator of the nation. The Indonesian language is not based on the language of the dominant Javanese but on the Malay dialect of the Riau Islands (as are the national languages of Malaysia and Singapore). Malay has long served as a lingua franca throughout the Indonesian Archipelago and was considered politically neutral so it could be adopted as the national language without offending any particular group. Another advantage is that it is spoken in neighbouring countries. As an (almost) artificial creation, the language does not carry cultural values specific to one particular group. For example, in Malaysia the Malay language has in the past been closely connected with Islam, and many Arabic loan words are in everyday use. In Indonesia on the other hand, Christian religious literature is freely available in Indonesian and the language is used in church as well as mosque. Indonesian makes less use of Arabic loan words, but borrows much more from Sanskrit, the religious language of the Hindus of Bali and the pre-Islamic Javanese.

Islam is the religion of approximately 90% of the population making Indonesia the most populous Islamic country. However, the state is secular and recognises four religions - Islam, Christianity, Buddhism and Hinduism. The zeal with which Islam is followed varies a lot. Java has converted to Islam within the past three hundred years and there are still many signs of the earlier Hindu religion especially in terms of sculpture and personal names.

The Javanese are the most important ethnic group in Indonesia in terms of numbers and political power. The majority of key government and army posts are held by Javanese. An important cultural feature of the Javanese is the 'wayang kulit' or shadow theatre already referred to in Section 5.1. This shadowiness or opacity is also displayed in other ways. To understand newspaper commentaries one must look very carefully between the lines. Through the use of ambiguity one is not forced to stick one's neck out by adopting an inflexible position - if the political tide runs in a different direction, one's statements can simply be re-interpreted. This pragmatism allows people to retain 'face', a concept familiar in all societies.

Although the government is highly centralised, its style is not strongly autocratic. Indonesians like to achieve consensus before taking any action. The consultation process slows down decision making but means that when decisions are taken they have the backing of the majority. However, the autocratic tendencies mean that the personalities of key Figures in the government can have a disproportionate effect on policy.

In order to forge national unity a national ideology has been devised. It has been made part of the life of the people through the education system. It is taught in all schools and universities; first-year university students attend a one week course on the 'pancasila' or 'five principles'.

These are:

1. Belief in the One and Only God;
2. Just and civilised humanity;
3. The unity of Indonesia;
4. Democracy guided by the inner wisdom of unanimity arising out of deliberation among representatives;
5. Social justice for all of the People of Indonesia.

10.2.2.3 Economic and Technological Policy - Indonesia

As a former Dutch colony, the country has inherited the Dutch civil code and the basic administrative system put in place by the Dutch. However the hostility engendered by the independence war and the replacement of the Dutch language by Indonesian as the language of education and government has meant the these laws are remote from the ordinary people. There is a widespread ignorance about many aspects of civil law. Indonesian law, based on the principles of 'pancasila', the five basic tenets of the constitution, has been developing to fill this gap.

In 1965 an army-led revolution brought Suharto to power. Under his leadership a change of economic direction took place. The country was gradually opened to foreign investment and free trade and is now considered a newly industrialising economy. An economic growth rate of 7 - 10% was regularly achieved until 1997.

The economic policy stresses attracting foreign investors by providing a favourable environment in terms of costs, taxes, labour force and physical infrastructure.

Indonesian is the medium of education at all levels. It is also the language of government and commerce. English is taught as a second language but the number of people fluent in the language is relatively small. Fortunately Indonesian is written in the Roman alphabet which simplifies the development of information systems - many non-Roman alphabets or character-sets are not available on all hardware platforms and not all GIS software can handle such characters.

Indonesia is developing very rapidly, and is open to any technology which will assist its development. The drive to find and adopt the latest technology is being led by Habibie, the Minister for Research and Technology at the time the project was carried out and now President. Habibie is an aeronautical engineer who trained in Germany and worked there for a number of years until President Suharto called him home to spearhead the modernisation of Indonesia.

At the time the case study was undertaken Habibie headed the Agency for the Evaluation and Adoption of Technology which is charged with researching the latest technological developments overseas and assessing the relevance of the technology to Indonesia. This agency also provides assistance to other government departments which are embarking on innovative projects.

In addition to this, Habibie headed the Batam Industrial Development Authority (BIDA).

10.2.2.4 The Organisation - BIDA

The Batam Industrial Development Authority (BIDA) has the task of developing Batam Island in the Riau Province, about twenty kilometres to the south of Singapore, as a manufacturing centre for 'high-tech' products for the export market. Batam was chosen for this development because of its proximity to Singapore where technological and managerial skills are readily available.

BIDA has extensive powers with regard to the administration of the island, in many cases over-riding the authority of the provincial government. The Agency was headed at that time by President B J Habibie and the island today is largely a reflection of his dreams and ambitions.

BIDA has its principle office in Batam, but also has a smaller office in Jakarta to liase with other government departments and potential investors. The office of the Head of BIDA is in Jakarta, but a Chief Executive Officer is resident in Batam. The structure is shown in Figure 10-7 overleaf.

BIDA is structured into several directorates which include planning, finance, construction legal affairs and marketing. The BIDA GIS has been implemented in the Planning Directorate but it is intended to extend the system to other directorates in the future.

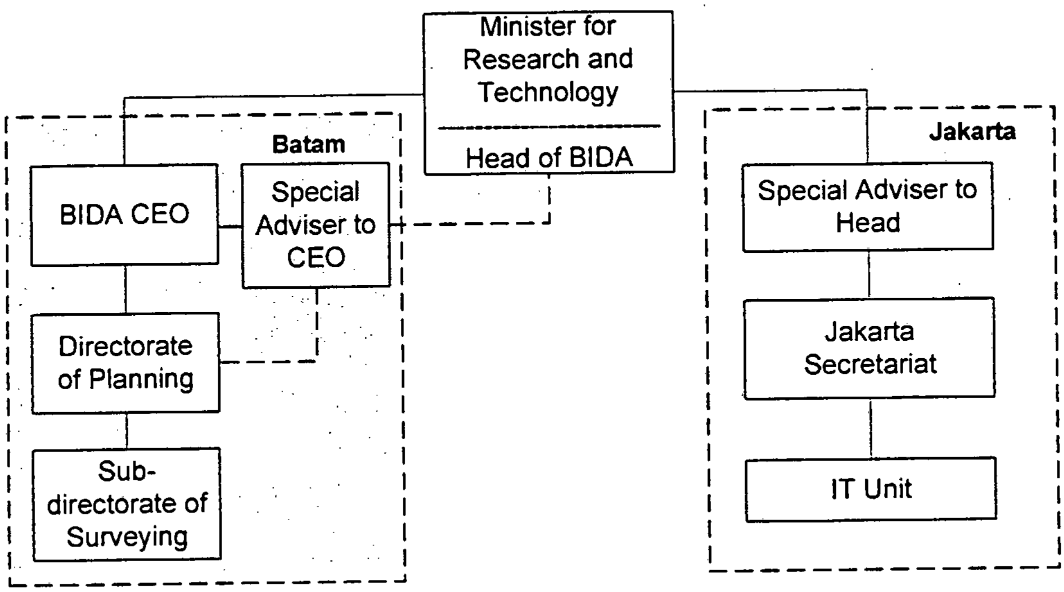


Figure 10-7 The BIDA Departments Involved in GIS Development

As a special development agency, BIDA does not employ permanent staff. All technical staff are seconded from other ministries and departments. Although some of the staff have been in Batam for several years most regard it as a temporary posting and there appears to be a lack of any strong loyalty to the authority or to the place.

The special adviser to the CEO, a senior engineer with project management experience, briefed the CEO (a retired army general) on technical matters. He took a leading role in the GIS project without filling any position in the project organisational chart and was effectively the decision maker during Phase I of the project. Early in Phase II several management changes took place which included the transfer of the CEO and his special adviser to other government posts in Jakarta.

10.2.3 Malaysia

10.2.3.1 Background - Malaysia

Malaysia is a medium-sized country covering 330,000 sq.km. including the Malay Peninsular and the States of Sabah and Sarawak on the island of Borneo. It is an ethnically mixed nation of about seventeen million people, roughly 35% Chinese, 50% Malay, 8% Indian, and 7% others (including the numerous indigenous peoples of Sabah and Sarawak). As a former British colony, the country inherited a British legal and administrative system. In colonial times the working language of government and administration was English which was also the medium of instruction in schools and universities. After independence in 1957, Malay became both the National language and the medium of instruction in schools. The government is now run largely in Malay, though most educated Malays are bilingual in Malay and English, while most educated Chinese speak Malay, English and a Chinese dialect. Note that the National Language is based on the Malay dialect of the Riau Islands. Since this dialect is also the basis of the Indonesian language, Malaysian and Indonesian are mutually intelligible, though rather further apart than British and American English.

In colonial times, the Chinese assumed a leading position in the economy while the Malays remained relatively backward. This disparity led to serious racial riots in 1969. In response to this the "New Economic Policy" was introduced. Its aim was to put at least 30% of the economy in Malay hands by 1990. In 1981 Mahathir became Prime Minister. Under his dynamic leadership the county has experienced almost continuous economic growth. This has only come to a halt in the past year. Since 1969 the country has been governed by the National Front, an alliance of racially based political parties. This ensures that minority races are represented in government and that their interests are protected as far as possible. On the other hand, the dominance of racially-based parties has prevent the emergence of any multi-racial parties strong enough to present an serious challenge to the government.

10.2.3.2 Culture - Malaysia

Malaysia shares many common features with Singapore. Both countries were governed by the same British colonial authority and Singapore was a State within the Malaysian Federation from 1963 to 1965. Britain still exerts a powerful influence on Malaysia - over the past thirty years hundreds of thousands of Malaysian students have studied in British universities and imbibed British values. Due to the population distribution and the use of the National Language, the dominant culture is Malay. The Malay culture is driven by Islam while the Chinese are predominantly Buddhist with a fairly substantial Christian minority. While Malaysia is not an Islamic State, Islam occupies a special place in the life of the nation.

The normal divisions between the government and private sectors have been widened by the fact that the Malays are in political control while the Chinese lead the way economically. While there are senior professional and technical officers of all races in the government service, the vast majority of the decision makers are Malay. The culture of government is Malay. Hence when handling government projects, one must take account of the particular cultural traits of the Malays.

There is much talk of the emergence of a common Malaysian culture and to some degree this is happening. A distinct Malaysian dialect of English is spoken by all races and the cuisine of each group is influenced by that of the others. However, religion would seem to place a limit on how far this can go. Chinese love pork which is forbidden to Malays. Religion also presents a barrier to inter-racial marriages. In politics too, the racial divide is maintained since government is in the hands of a coalition of racially-based parties.

A further important factor is the sensitivity of relations between Malaysia and Singapore. Singapore was a member of the Malaysian Federation between 1963 and 1965. The State Government of Singapore favoured a non-racial policy while the Federal Government wished to give preference to Malays. Singapore refused to implement such policies, so the issue was resolved by separation. Though this all took place over thirty years ago, and despite the high degree of integration between the two economies, both sides are still very touchy and small differences are played up by press and politicians on both sides.

10.2.3.3 Economic and Technological Policy - Malaysia

As far as economic development goes, Malaysia stands mid-way between Singapore and Indonesia. The government has a "Vision 2020" meaning that

Malaysia should be a developed country by the year 2020 with an income level similar to that of middle income European countries.

From independence until the start of the nineties, the entry of foreign workers was strictly controlled. Eventually the pace of economic growth was threatened by a manpower shortage and it became easier for foreigners to obtain employment passes, particularly in the field of advanced technology. To encourage foreign companies to establish a presence in the Multi-media Super Corridor, companies are able to bring in skilled foreign workers with very few restrictions.

Despite the recent economic setbacks, the government is still driving towards a 'high-tech' future. While many government projects have been delayed or cut back, funds are still being made available for IT projects.

10.2.3.4 The Organisation - Federal Administrative Centre

As was mentioned in Section 10.1.3.1 above, the Federal Administrative Centre Authority (FACA) was established to supervise the development of the new city, and to manage it thereafter. The structure of the organisation is shown in Figure 10-8 below.

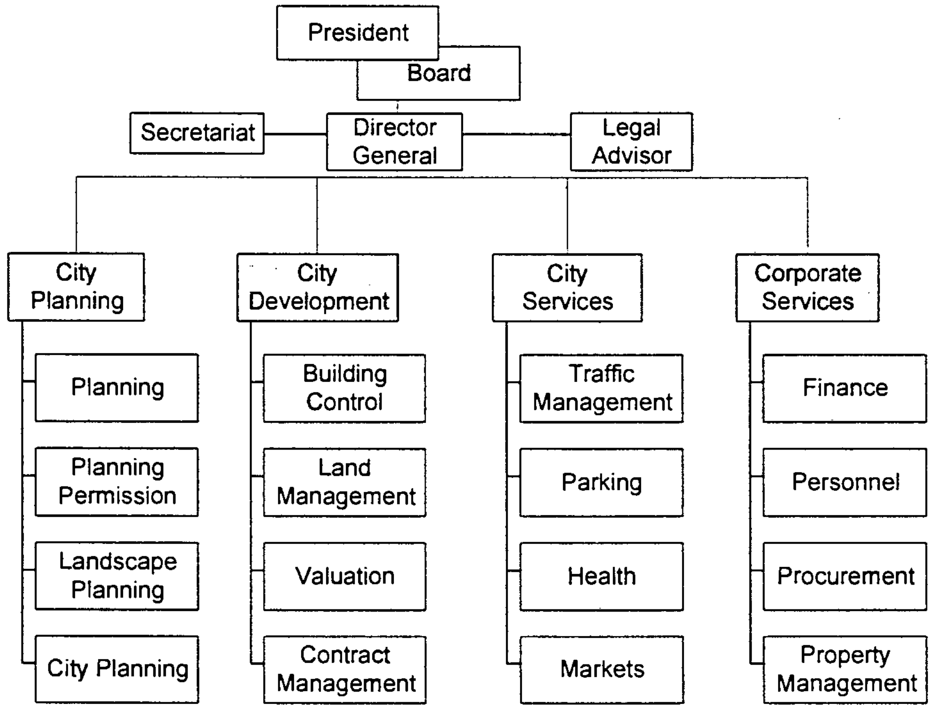


Figure 10-8 The Organisation of the Federal Administrative Centre Authority

In line with what was said above about Malay dominance in the government, more than 95% of the officers are Malay. The implication for system development is that contractor's employees, no matter what their race, nationality or religion, must respect Malay sensitivities and show an understanding of their culture. For example, a non-Muslim would give offence by becoming exasperated by his counterpart leaving a meeting for prayers.

As the Federal Administrative Centre is in an early stage of development, planning and construction are the most important issues, and it is these issues which are addressed by Phase I of the Federal Administrative Centre Information System.

What was said above about Malaysia in general is especially true about the Federal Administrative Centre. The Authority has the vision of becoming a modern transparent administration, using the latest information technology to conduct its affairs expeditiously, and to serve as a model administration, not only for Malaysia but for the rest of the world too.

10.2.4 Comparison

The table below shows the major cultural characteristics of each country, and provides a convenient reference for comparison.

Feature	Singapore	Indonesia	Malaysia
Language	English	Indonesian (Malay)	Malaysia (Malay)
Characteristics	Respect for Authority	Consensus building	Hardworking and Conscientious
	Hardworking and Conscientious	'Laid back'	Political intrigue
	Trust in the law and judicial system	Little confidence in judicial system - many people are unfamiliar with the broad concepts of the law (other than the Constitution)	Trust in the law and judicial system
Religion	Buddhism, Christianity, Islam	Islam, Christians few but influential	Malays - Islam Chinese - Buddhist, Christian

Feature	Singapore	Indonesia	Malaysia
Education	Tertiary education is of a standard similar to that of developed countries. Many Singaporeans also study overseas, particularly in UK, Australia and USA.	The standard of universities differ widely. Many senior civil servants have studied overseas in US, UK, Australia, Germany and other European countries	Tertiary education is of a standard similar to that of developed countries, though Malay medium education presents problems for some. Many Malaysians also study overseas, particularly in UK and Australia.
Connections	A very serious effort has been made over a long period to eliminate corruption. Consequently personal friendship and/or the offering of favours are unlikely to win contracts.	Pay in the civil service is low, and it is sometimes suggested that favours granted to civil servants may influence the award of contracts. These favours may take the form of part-time employment, scholarships etc.	Civil Service pay is competitive and corruption is at a relatively low level.

Table 10-1Comparison - Key Features of Indonesian, Singaporean and Malaysian Culture

10.3 The Developers

10.3.1 The Developers - ILUS

The Integrated Land Use Systems was developed by the Singapore branch of the German company Siemens. Prior to the ILUS project, this company's Information Systems Division had not been active in Singapore. However, on winning the project through open tender, the company deployed a small core team from Germany which started building up a Singapore team to implement the project.

10.3.2 The Developers - BIDA GIS

The BIDA GIS was also developed by the Singapore branch of Siemens Information Systems Division. Though the projects teams were undertaken by different teams, the teams shared an office and shared experiences extensively.

This benefited the BIDA GIS project because solutions had already been found for many of the problems which cropped up.

10.3.3 The Developers - FACIS

At the beginning of 1995 the key members of the development teams which had built the ILUS and BIDA GIS left Siemens to form a new company called Nova Sprint Consulting (NSC). Starting with six founding members, NSC grew rapidly and at the time of writing has over a hundred employees, with offices in Malaysia and Indonesia.

NSC is a Singaporean company. Apart from the writer (a white South African), the shareholders and directors are all Singaporean Chinese.

For the reasons cited above in Section 10.2.3.3, it is difficult for non-Malay companies to win government projects in Malaysia. The government see the acquisition of technology by the Malay community as a major factor leading to the uplifting of the Malays. Hence 'bumiputra'[†] companies are favoured in the award of contracts. In the nature of things, such companies seldom have the experience to undertake the development of large information systems. To submit credible proposals they must link up with non-bumiputra local or foreign firms.

As a tactic to win the FACIS project, NSC formed a joint venture company with a bumiputra company, Single Network (SN). The joint venture company is called Town Management Services or TMS, and is owned 70% by SN and 30% by NSC. As SN lacked the necessary skills to develop the system the design and development work would be sub-contracted to NSC. To effect some technology transfer, approximately 20% of the work was sub-contracted back to SN, while NCS took the balance. The role of TMS is project management. In this area an experienced project manager from NSC works closely with his TMS counterpart.

The structure is shown in Figure 10-9 overleaf.

[†] 'Bumiputra' is a Malay word meaning 'prince of the soil' used to refer to indigenous Malaysians in contrast to Malaysian citizens descended from immigrants.

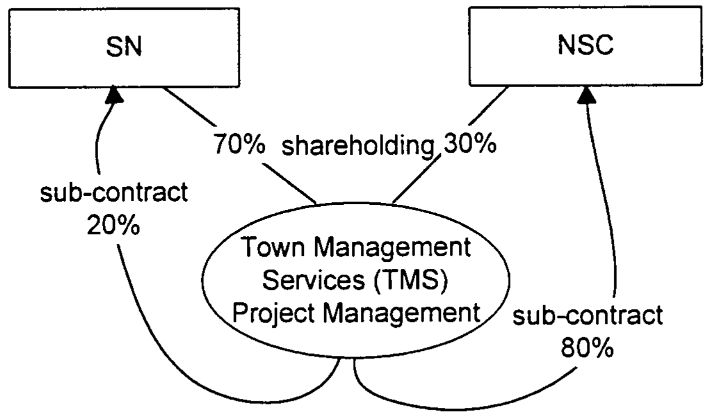


Figure 10-9 The Developers' Structure

10.4 Development Methodology

Both ILUS and BIDA GIS were developed using Siemen's 'Process Engineering' described in their 'Process Engineering Handbook'. It is similar in essence to most other software engineering methodologies. The handbook breaks the development process down into a number of stages, each marked by a milestone, normally the delivery of a document. The handbook prescribes the format and contents of documents to be delivered at each stage. The stages are designated by numbers e.g.

- P10 P20 P30 — Problem Analysis Phase
- A10 A20 A30 — System Analysis and Requirements Specification
- T20 T30 — Technical Specification and Development
- B70 — Live System under maintenance

'Process Engineering' is a 'hard' methodology which leaves little room for flexibility. Documents are submitted to the customer at each milestone for his approval. After the approval of a milestone document, the customer cannot re-open any matter without incurring additional costs, whether or not the customer actually understood what he was signing. A failure of communication due to language problems or culture is likely to lead to disputes in this context.

In the case of FACIS, a different approach was taken, much more in line with the methodology advocated in this thesis. The interacting systems of customer, developer, government and competitors were studied and an approach was adopted which it was hoped would satisfy the customer while neutralising potential competitors. This approach took cultural, linguistic and political factors into account. An advanced technological solution was developed at the same time.

10.4.1 Methodology for ILUS Development

Process Engineering was a key factor in winning the ILUS contract. The National Computer Board, which was supervising the project, knew the enormous complexity of the project and realised that it could only be completed successfully using a rigorous development methodology. One consequence of using this methodology is that every aspect of the system is comprehensively documented.

As can be seen from the cultural analysis given above, this approach is in line with Singaporean culture. A firm framework is rigorously enforced.

10.4.2 Methodology for BIDA GIS Development

As the BIDA project was very limited in scope compared with ILUS it was decided that Process Engineering could be relaxed in certain respects. This was done by combining the detailed User Requirement Specification (A30) with the Technical Specification (T20). This reduced the volume of documentation substantially. In most other respects the development adhered closely to the Process Engineering Handbook.

By the time Phase II of the project started, toward the end of 1993, the developer's office in Singapore was in the process of being certified in terms of ISO9002. A Quality Manual and a Quality Procedures Manual, based on the process engineering technology had been prepared, and these procedures were applied to the BIDA project - one of the projects subjected to external quality audit.

10.4.3 Methodology for FACIS Development

Based on the case presented to FACA, as well as the track record demonstrated by the NSC staff who had worked on the ILUS and BIDA GIS projects, Town Management Services (TMS) was initially appointed to prepare a Strategic Information Systems Plan for the whole organisation, and subsequently to undertake the implementation of Phase I. In his role as Consultant to the Board and as a director of NSC, the writer has been able to exercise a strong influence on the development of the system.

Right from the beginning the information system was viewed as an integrated whole. The starting point was an understanding of the organisation's business processes. As mentioned above, a firm of management consultants had proposed an organisational structure based on the duties and responsibilities laid on a local authority under the various laws relating to local government. The report prepared by this firm had been adopted by the Board, and was taken as the starting point.

The Strategic Information Systems Plan identified the work flow for each business process. Links between departments and with outside agencies were identified. The major data entities were noted and data used by more than one department was identified as a part of the common corporate database. Dependencies between sub-systems, and priorities for implementation were established. Based on this report, a project plan for Phase I implementation was drawn up and accepted by the client.

As discussed in Chapter 7, 'incremental development' is considered the best approach to this type of system. As user requirements were finalised, sub-systems were built to enable users to familiarise themselves with the system while further development was in progress.

Detailed user requirements were developed in a iterative fashion by conducting interviews with middle management, creating or modifying an appropriate user interface, followed by a presentation to senior management. This was repeated until all sides were happy with the result.

Actual development was done using modern tools. Oracle 8 with an extension to handle spatial data was used for the corporate database. Formida, a development tool for building end-user applications with spatial data was used to generate the user interface for GIS applications such as Development Planning and Planning Permission. For non-graphic applications Powerbuilder was the tool of choice. These tools have many features to facilitate development. FACIS Phase I was completed in nine months (not including the preparation of the Strategic information Systems Plan). In comparing this with the more than three years spent on ILUS the difference can be accounted for by:

1 the greater flexibility of the development methodology
2 the experience of the key members of the development teams gained in ILUS
3 The increased productivity achieved with modern development tools

10.4.4 Discussion

The "Process Engineering Handbook" follows the 'hard' systems approach. The development process is viewed as a technical problem which can be solved provided that all the right steps are carried out in the right sequence.

The computerisation programme in the South African Surveyor General's Office (SGO) in the late eighties and early nineties provides a striking example of system development 'by the book' leading to a technically correct system but one which the customer did not want when it was finally completed. It no longer met the (changed) requirements. In the case of ILUS and BIDA-GIS, pressure from the customer was one of the factors which convinced the development team that flexibility and adaptation were needed, especially in the face of rapidly changing technology.

In the ILUS project when changes in technology threatened the success of the project, a new and more ambitious proposal was put to the customer. The customer accepted the proposals and was rewarded with a very advanced system for its time. Interestingly enough, ILUS users are now requesting some of the features which they have seen in FACIS.

Viewed in system terms, the planning function (*System 4*) must be included in the development system, and must be able to influence the executive to adopt its recommendations.

With FACIS the circumstances were such that the full planning cycle could be implemented. Secondly at the time the project started, the writer had just completed the first draft of this thesis and was fortunate enough to be in a position to apply a methodology based on systems theory to the implementation.

10.5 System Implementation

10.5.1 Implementation of ILUS

10.5.1.1 ILUS Project Team

The project team was structured as shown in Figure 10-10 below. The project was overseen by a Steering Committee made up of a senior manager from the National Computer Board (NCB), the Chief Executive Officer of the URA and the Managing Director of the company carrying out the system development. The Project Manager, Financial Controller and the Heads of the user departments were also members of the committee. The Steering Committee met to review progress at project milestones and to resolve disputes between the developer and the URA which could not be solved at Project Management Committee level. NCB was not a party to the contract between the developer and URA, but filled the role of consultants to URA.

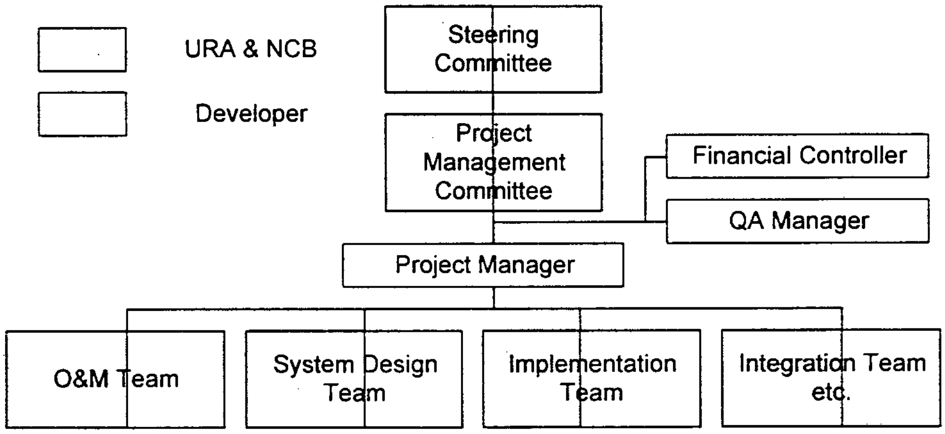


Figure 10-10 The Structure of the ILUS Project Team

Each working group contained members from both the developer and URA. The intention was to transfer technology from the developer to the URA team members, so that URA could undertake development of further application sub-systems by themselves after the completion of the ILUS project.

10.5.1.2 ILUS Development

The pilot project was intended to familiarise users with GIS concepts and with the GIS software. The project contained a sub-set of the Development Application system and included the capturing of data for one of the most intensively developed parts of Singapore. The pilot system was successfully launched and the feedback obtained was incorporated into the design of the main system.

A large team, many of whom were contract workers from China and India, undertook the coding of the application functions. That these programmers were able to come in, and work solely from the technical specification with no previous knowledge of the project is testimony to the rigorous way in which the specification was drawn up and checked.

System integration was a major challenge. The user interface or EIP described above provided the integration framework but was itself very complex software. There were inevitable mistakes in specifying parameters so that modules which worked by themselves did not work correctly in context and had to be referred back to the programmer for correction. This led to friction between developers and integrators and increased the stress level all round. The work was not technically difficult but demanded patience and perseverance.

10.5.2 Implementation of BIDA GIS

10.5.2.1 BIDA GIS Project Team

The BIDA GIS Project Team was structured according to the principle adopted for ILUS. Key team members were supplied by the developer, while each work group had representatives from BIDA.

There was also a representative on the Project Steering Committee from the National Technology Agency (BPPT).

The Steering Committee comprised the CEO, Director of Planning, Director of Finance, Special Adviser, and Project Manager from BIDA; the General Manager, Project Manager, Sales Manager, Quality Assurance Officer from the developer's Singapore office, and the IT Manager from the developer's office in Jakarta.

10.5.2.2 BIDA GIS Development

Development was divided into two phases, each approximately a year in duration. The first phase was considered a pilot project to introduce GIS technology to BIDA. The effort was focused on database design and data capture. In addition a small number of functions needed for the land allocation application were developed. During this phase a complete digital topographic database based on photogrammetric mapping at 1/2000 was created, and the master development plan for the island was digitised.

In the second phase, detailed user requirements specifications were prepared for two applications, the land allocation system and an environmental monitoring system. According to contract, development should have stopped at this point, but due to pressure from BIDA the land allocation system was completed in all respects.

10.5.3 Implementation of FACIS

10.5.3.1 FACIS Project Team

The business arrangements for the FACIS development are outlined in Section 10.3.3 above. The interface to the customer was through the TMS Operations Manager. This post was held by a Malay who was a qualified Town Planner, with many years in local government service. He was able to identify with the customer in terms of race and religion, and also in terms of his previous professional experience. Coming from this background he was able to communicate effectively with the client.

Technical expertise was available within NSC from the various sub-system Team Leaders, and from the Consultants.

The FACIS project team was structured as shown in Figure 10-11 below:

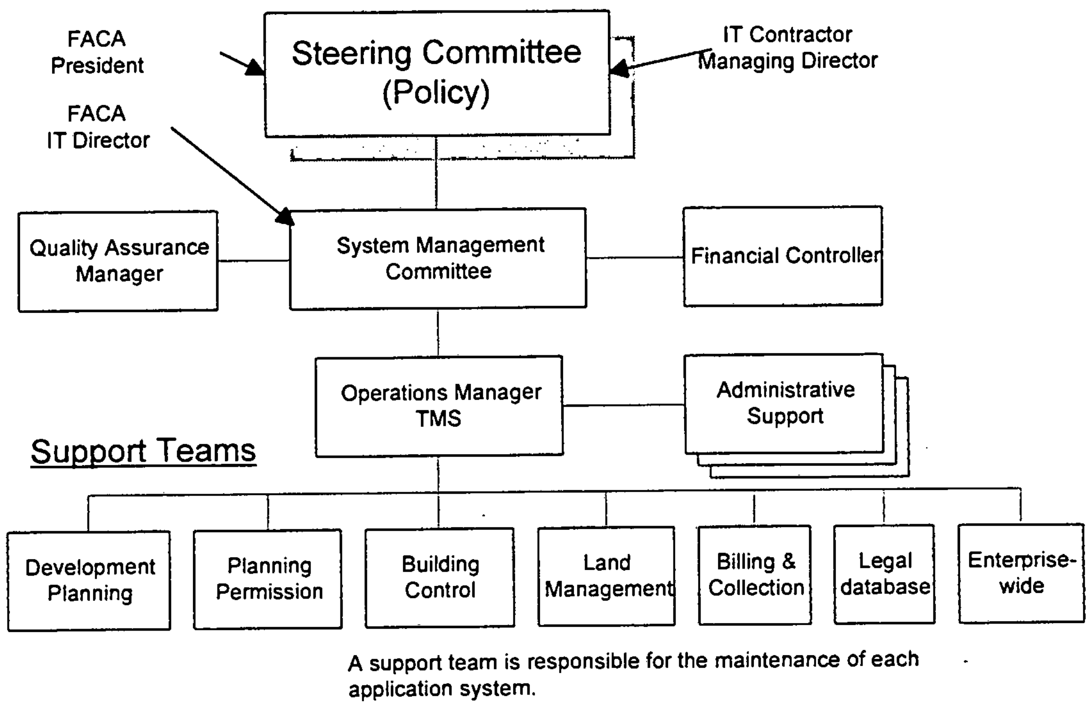


Figure 10-11 System Development Organisational Structure

10.5.3.2 FACIS Development

After the Strategic Information Systems Plan had been completed, the scope of work for Phase I was defined. Factors affecting this definition were priorities as defined by the users, available manpower at NSC, dependency between systems, and the users' expectations as to time frame. Figure 10-12 overleaf illustrates the relationship between the various application sub-systems and organisational units. From this diagram some idea of the scope of the project can be obtained.

The next step was to carry out a study of the users' requirements. An important skill at this stage is to keep the users' expectations within the bounds of what is technically feasible. If this is done discretely, the user will have no idea that his expectations are being managed.

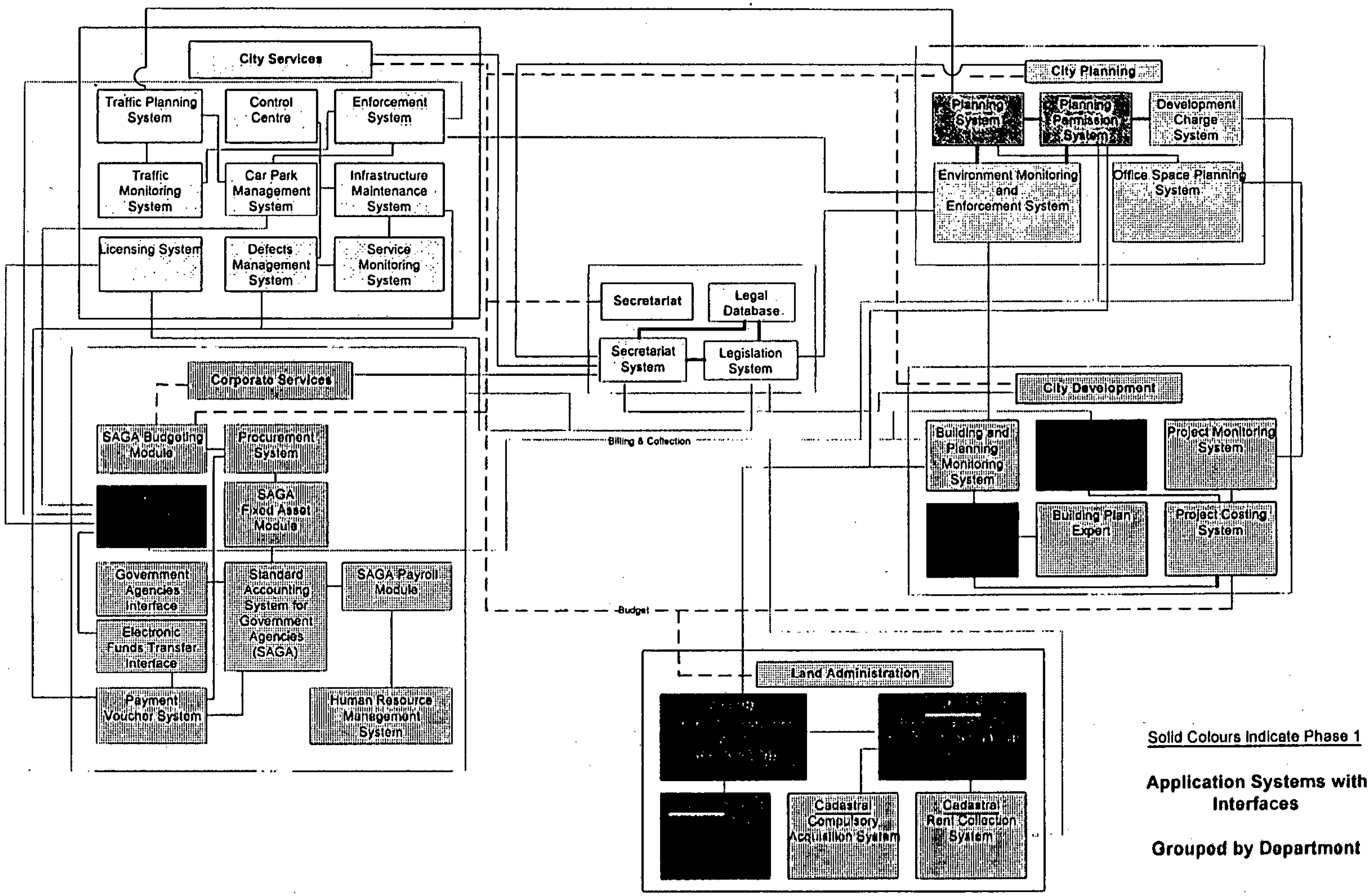


Figure 10-12 Overall System Concept

Because the users needed the Phase I sub-systems as quickly as possible to handle the flood of development applications, a short time frame for development was imposed. Development started in parallel with the user requirements study and prototypes were used in demonstrations to further elucidate the requirements.

Once the requirements had been agreed for each specific sub-system, full development went ahead using resources in Malaysia and Singapore supported by a number of contract programmers. In parallel, users' manuals and training materials were prepared. At the time of writing, software integration testing is taking place. This will be followed by user training before the system goes 'live'.

10.6 Implementation Problems

Due to the complexity of these projects it was understandable that problems should be encountered. These included technical problems relating to both hardware and software, as well as organisational problems.

10.6.1 General Technical Problems

Singapore is a very sophisticated IT market. All the large American vendors of hardware and software are present and compete vigorously in the market. This was a shock to the Siemens management who had had relatively little exposure to overseas IT markets other than in South Africa where Americans were forbidden to operate. After the pilot phase had been completed, the developer was left with no choice but to move to Unix, a windows-based user interface, and a commercial relational database in order to keep the project.

These software changes had been planned but there was no sense of urgency until pressure came from the ILUS project. In fact, in many ways the development of SICAD/Open was driven by the requirements of the ILUS project.

ILUS and BIDA GIS were the first projects to use SICAD/Open and were used by the developers as test sites. The situation was very different from installing a stable product, and the many defects in the software soured the relationship between the system developers and the customer. Fortunately when the SICAD developers in Germany realised the seriousness of the situation, they made a very determined effort to solve the most serious problems. Performance was the greatest of these.

10.6.2 Problems Specific to ILUS

The ambitious aims of ILUS resulted in a number of technical problems with both software and hardware.

Software

The base GIS software did not have sufficient capability to perform all the functions required by ILUS. To meet these requirements a number of new functions were developed. These have since become part of the standard GIS product.

Problems were also encountered in achieving the same 'look and feel' on Windows and Unix platforms.

Hardware

Because of the large number of users, performance became a critical issue. This was eventually resolved by upgrading the hardware.

10.6.3 Problems Specific to BIDA GIS

Software

With BIDA the system design took place within the known capabilities of the software. Thus the only software problems encountered were defects, in other words documented functions which did not function as they were supposed to. Such cases could generally be solved by 'work-around'. Here the cultural differences between Singapore and Indonesia were very apparent. In Singapore the tendency is to look at the letter of the contract, whereas in Indonesia problems are more likely to be overcome through negotiation.

Scope of Project

There was disagreement between the developer and BIDA over the scope of the project. There was an initial misunderstanding on the part of the customer about what he was getting. Although the scope of the work was clearly set out in the contract, the customer did not understand the implications. This was a communication problem. It could have been overcome through management training at a very early stage of the project. A subsequent project for the National Oil Company in Indonesia was started with one week of training for senior officers before the scope of the project was determined. This training enabled the officers to understand what they were specifying.

10.6.4 Problems Specific to FACIS

One of the most striking features of the FACIS project is the way in which the relationship between the key parties on both sides have been maintained over more than two years.

Many technical problems have been avoided by managing the users' expectations. The consultants only proposed solutions known to work. Even so, at the integration stage it was discovered that when the document management system (PC-Docs) was running, the PowerBuilder modules 'crashed'. Fortunately, before this could become an issue, the problem was resolved by the release of a new version of PowerBuilder. This problem illustrates the risk and difficulty of integrating even tried and tested products.

Apart from such minor issues, success up to this point can be attributed to a good relationship with the customer, reinforced with delivery of good products on time.

10.7 Conclusion

10.7.1 Success and Failure

A project can only be said to be a total failure if it is abandoned and no hardware or software is installed. Relatively few projects end like this, but there is a wide range of outcomes between total failure and total success. The primary attributes of a successful development effort are:

- Completion within budget
- Completion on time
- System complies with User Requirements Document
- System meets users' expectations
- System is fully utilised

These attributes will be considered for each system.

10.7.1.1 ILUS

Completion within budget

Considerably more was spent on ILUS than was originally planned. The Enhanced ILUS System (EIS) represented a change to a much broader concept. The product finally delivered was much more extensive and complex than that initially planned. This was understood by the customer who increased his budget accordingly.

On the other hand, the developer incurred substantial costs in meeting the functional requirements of the system. Numerous additional GIS functions had to be developed. The company was able to justify this expense as customer-driven product development.

The developer incurred further substantial costs in upgrading hardware to meet performance specifications. Strictly speaking therefore, the project cannot be regarded as a success in terms of budget constraints. On the other hand expenditure beyond the budget can be regarded as an investment which is being repaid now in the form of further development and maintenance contracts. It also provides a first class reference site.

Completion on Time

The original contract period was lengthened due to the new specification for the EIS. However, completion was about six months late from the developer's point of view, with user acceptance a further six months later.

The reason for this is clear. There were unrealistic expectations from both the developer and the URA. The difficulties of estimating software development effort is well known, and sales staff and management put a great deal of pressure on technical staff to commit to early completion dates.

System Complies with User Requirements Document

In this respect the system was completely successful. The change control system ensured that all changes requested by the URA were incorporated into the User Requirements Document. The customer's acceptance testing was exceptionally thorough. So when the user acceptance was finally given all the functional requirements were fulfilled.

System meets users' expectations

Overall, users' expectations have been met. Users with the older workstations complain of poor performance, but the URA is replacing these machines as budget allows. The *Land Safeguarding* and *Roads* systems are relatively simple and are used by technical staff who have realistic expectations. The *Building Application* system is predominantly text-based and has received a positive acceptance from users. The *Development Application* system is the most complex system combining graphics, textual data and complex workflow management. Because of its complexity it is inevitable that a number of defects have been found in the system, and while these are generally resolved within a day or two, they do cause some frustration.

The development team is being given further development work by the URA. This provides some evidence of customer satisfaction. It was stated above that it was the intention of the URA to do further development themselves. They are now capable of this but find it more cost-effective to contract out the work.

System is fully utilised

The system was designed from the start to automate certain aspects of the business processes. The management has been fully committed to the project throughout and the system is used to handle all areas for which data is available. The data conversion process is now almost complete.

10.7.1.2 BIDA GIS

Completion within budget

Both phases of the project were completed within budget. The relatively simple nature of the project, in comparison with ILUS, made estimating much easier, and technical problems with the GIS software were solved in the ILUS project in time for the results to be used in BIDA.

Completion on time

Phases I and II were completed on time in respect of the work specified in the contract.

System complies with User Requirements Document

The system complies fully with the User Requirement Document. However, the developers subsequently learnt that the users' requirements had not be documented completely accurately because of the customer's lack of experience and language difficulties.

System meets users' expectations

The system initiation was a top-down process. The users were not involved in deciding whether to have a system or not, or what system to have. Under these circumstances it was surprising that any of the staff adopted the system enthusiastically, though in fact the technical staff have done so.

A senior officer in the IT unit was opposed to the project from the start. His opposition was based on his opinion that the proposed system was too complex for BIDA to handle, and that the system being offered did not represent 'state-of-the-art' technology. This officer maintained a steadfast opposition to the project and could not be by-passed as he was always asked for his professional opinion on technical matters. He was a 'thorn in the flesh' to the developers.

System is fully utilised

The system is not fully used for the purpose of processing applications for the allocation of industrial land for which it was designed. However, it contains a complete topographic database of Batam, and is used extensively for map production.

It is anticipated that the system can be brought into full operation relatively quickly if the outstanding contractual problems referred to above can be solved.

10.7.1.3 FACIS

Completion within budget

Thus far the project is within budget, though due to the devaluation of the Malaysian currency, the profit will be much less than anticipated. On the other hand, the economic slow-down in Malaysia has made it much easier to find qualified and experienced staff.

Completion on time

At the time of writing, Phase I is nearing completion (User Acceptance Test) on schedule. This has been achieved through careful project planning and management. Monthly project status meetings and reports enabled potential problems to be highlighted and resolved before they could delay the project.

System complies with User Requirements Document

The development methodology, moving from users' requirements to functional and technical design, ensures that each requirement is matched by a function or group of functions. Acceptance testing is based on actual case material which reflects the users' needs. Hence compliance is achieved.

System meets users' expectations

Only time will tell whether the system meets the users' expectations. The probability is that it will, given that none of them have ever used anything similar in the past, and that the key users have been very enthusiastic in meetings with the developers.

System is fully utilised

There is a high probability that the system will be used intensively. There is strong political pressure from the top for this to happen, both to increase efficiency and to reflect Malaysia as an advanced knowledge-based society.

10.7.2 Lessons

ILUS is one of the largest and most complex geographic information systems in the world. At present the system has more than two hundred users, about 2000 Oracle tables, and a growing database which already contains 30 Gigabytes of land-related data.

The integration of work flow, project event monitoring (PEM), and spatial and non-spatial data into a corporate information system was an immensely challenging task which had not been undertaken before, certainly not in South East Asia. Under these circumstance it would have been incredible if nothing had gone wrong, nevertheless, all concerned persevered to bring the project to a successful conclusion.

The reasons for this success include:

- Total commitment by senior management of customer and developer.
- Technical skills to overcome technical problems.
- Continuous interaction between developers and users.
- Mutual confidence between developers and customer.
- A culture both hungry for innovation, and obedient to superiors.

The National Computer Board (NCB) took the lead in planning and initiating the project. It would have been easy for the CEO of the Urban Redevelopment Authority (URA) to have distanced himself from the project and allowed the NCB to take the blame for any failure, instead he remained committed throughout and in so doing, gave a lead to his staff.

The developer also had a lot at stake. Failure would have dealt a blow to his credibility in Singapore, where the company has a major stake in the economy. In comparison with the company's total business, the ILUS project was a small matter which could not be allowed to affect the main business.

Some of the planning procedures used in the URA could not be customised using the standard GIS software. However, technical skills were available to modify the software to address these problems.

The NCB team were involved in the development throughout, both as developers and as consultants. Much of the work was done in the NCB office in the URA building. The result of this was that developer's staff were at the URA every day meeting and mixing with the personnel. This built rapport and a constructive attitude to problem solving.

The customer had confidence in the developer' ability to complete the project successfully, if only because of the enormous financial resources the company possesses. For its part, the developer knew and understood the Singapore culture which gave it confidence in dealing with the URA.

The Singapore love of high technology resulted in a workforce eager to try out new ways of doing their work. Many employees also see skills with a new technology as a key to job mobility and higher salaries. For these reasons the staff were keen to learn and to use the new system. The cultural value of obedience to seniors obviated the human relations problems which sometimes occur in other environments e.g. Greece where Assimakopoulos (Campbell 1995) reports that "*microcomputers and workstations are perceived and managed as if they were mainframe computers mainly because of the unwillingness of the end-users to accept computer use as a part of their everyday jobs.*"

The relative failure of the Batam project can be attributed to:

- Lack of commitment by senior management in BIDA
- Failure by the developer to understand some aspects of Indonesian culture, in particular the way in which government projects are handled
- The system development team in Singapore were responsible for the execution of the project and were in day to day contact with the customer, but were commercially responsible to the developer's Jakarta office. Because of this contractual relationship it was not possible for the project manager to make necessary changes to the project without the agreement of the manager in Jakarta.
- Poor communications between Batam and Jakarta on both the developer and BIDA sides complicated the development process.
- The opposition of the Head of IT in Jakarta. This should have been dealt with early in the project by bringing him into the team to share responsibility for successful system implementation.
- A project phase which did not coincide with a completed product. Project phases were based on financial rather that technical criteria.

How it could be done better in future:

- Each phase should deliver a completed product <u>which can be used</u>.
- The key management and technical staff must be identified e.g. special adviser to CEO and Head of IT in Jakarta, and brought into the development process.
- Due regard must be given to local business practices in managing the development contract.

- Sub-contractors should only be used for technical work such as programming or cable-laying, where there is little or no interaction with the customer. From the customer's point of view, all interaction should be with the principal. In the case of BIDA the project team were not competent to discuss any issue which affected contractual arrangements or payments. All these issues had to be referred to Jakarta causing delays and frustrations. The distinction between the developer's Jakarta and Singapore offices was not clear to the customer who regarded the two as a single entity.

In FACIS the development was entirely in the hands of a local company. This gave the developers the freedom to undertake the project so as to apply the lessons learnt in ILUS and Batam. This is an important point because many Europeans have difficulty in accepting that they can learn anything from Asians or that they need to take culture into consideration. They also tend to impose their views when they are in control.

Secondly, at the time of starting the FACIS project, the bulk of this thesis had been written and it was possible to apply the lessons learnt to FACIS.

These advantages have enabled the developers to avoid the problems encountered in the earlier projects.

11. CONCLUSION

Technical competence is certainly a condition for successful system development, but it is not a sufficient condition. Computer-based information systems are developed within social systems composed of people who are "*impelled by ideas, knowledge, and hopes and desires. Who harbour intentions.*" (Phillips 1992, p.2) The key to success in system implementation is to understand this. From this it follows that the principal stakeholders must be identified and their hopes, desires and intentions analysed.

An approach to the development of computer-based information systems based on a systems view of the organisation has been presented above. This approach has a number of advantages over that currently adopted in the great majority of cases. Some of these are mentioned below:

1) Users and developers alike are made aware of the role of a computer-based information system within an organisation. Many systems are developed in which neither party looks beyond the technical aspects.

   Why should an organisation embark on the development of a computer-based information system? The only valid answer to this question is that it is done to improve both the efficiency and efficacy of the organisation's business processes. If the answer is that some of the staff enjoy using computers, or that communication via e-mail is very convenient, or that information can be retrieved very much faster, or that the organisation must have a computer system to be modern, then - desirable though these features may be - the whole point has been missed. The development process is focused on the wrong target and the result is unlikely to be completely satisfactory.

2) Development takes account of the cultural environment and the technical skills of the organisation. The system is designed from the start in such a way that the people who will use it and maintain it can relate to it.

3) The approach provides a framework within which to plan and implement the system. It encourages the process of identifying and carrying out the various tasks in a systematic way. As has been shown, this minimises risks and helps to ensure that the system hardware and software is delivered and

installed on time, and that the application software development is not only delivered on time, but also meets the system specification. The approach also ensures that the resulting product is robust and performs correctly through the systematic application of quality control measures.

4) The systems model of the organisation shows where potential problems will arise in the area of group behaviour and inter-personal relationships. The steps necessary to facilitate organisational change can be refined, taking into account the existing corporate culture and the more general cultural environment. It is through this interaction that the developers are able to assess the technical capabilities of the users, and to keep the users expectations in touch with reality. By building effective personal relationships between developer and customer, many problems can be resolved before they escalate.

5) There is a close correspondence between systems thinking and the object-oriented system design methodology. If object tools are used to model the organisation and its business processes, the design of the corporate information system is greatly simplified. The system can be specified by a further de-composition of the tasks identified in the business process model.

   The advantages offered by the use of object-oriented technology are well known, and include the saving of time and effort through the re-use of objects and greatly reduced maintenance resulting from the encapsulation of objects i.e. the code inside an object only affects data appearing in the object's (limited) interface.

   Object technology is particularly well suited to handling spatial objects. The basic graphic elements of point, line, and polygon serve as building blocks to create more complex objects modelling real world objects. This model is much closer to reality than relational models and so is much easier for non-experts to understand.

6) The system model provides an ideal basis for the corporate information systems plan. This greatly simplifies the work involved in further extensions to the information system.

7) Consideration of the steps necessary to bring about organisational change will reveal changing roles throughout the organisation. Everyone whose role changes will need training in order to perform his new role successfully.

8) An integral feature of the open system is its control and monitoring function. Thus when system development is viewed from the systems perspective, quality assurance cannot be overlooked. Quality assurance procedures will therefore be planned and applied in a systematic way. This results in a better quality product.

GIS must now be brought fully into the main stream of information system development. There is a need for developers who have a sound understanding of spatial data <u>and</u> who also understand the systems approach to development. Such people will build technically sound systems which will work because they are carefully tailored to the users' organisation, taking into account its culture, power structure and way of working.

The ILUS case study presented above shows that when the correct relationship exists between the developers and users, success is possible even in the face of serious technical problems. Fortunately, the users' culture was such that a 'hard' systems approach was appropriate. On the other hand, the BIDA GIS illustrated that misunderstanding between any of the parties can result in failure, even though there may be few technical problems.

The lessons learned in these two projects have been applied in the FACIS project. The project is on-going, but the indications at this point, with Phase I complete, are that the project will achieve a high degree of success.

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